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# Independent Research and Independent Exploratory Development

ANNUAL REPORT FISCAL YEAR 1972

NAVAL ELECTRONICS LABORATORY CENTER San Diego, California 92152

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# Foreword

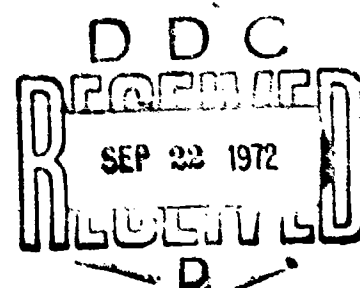
For the 1972 highlighted tasks under the NELC IR & IED programs, the choice of several efforts which are at the interface between electronics, optics, and solid-state physics is symptomatic of the thrust of technology on an international level. Discipline boundaries have blurred, the once formidable barriers between research scientist, development engineer, and production engineer are yielding to the need to cut down the time and cost of the RDT&E cycle. At NELC, the discretionary funds give the Center the opportunity to exercise initiative in accelerating the process in an experimental fashion free of many constraints that accompany sponsored tasks.

The fiber optics program showcases many of the intrinsic merits of what can be done with discretionary funds. A major improvement in the control of a materials production process, the development of optical fibers, a broad existing capability at NELC in electro-optics, and an unanswered Fleet problem at NUC together gave rise to a request for additional funds to the Director of Navy Laboratories which was approved. The extension to intraplatform data transfer followed. During the past year, other sponsored applications were initiated while the practical engineering considerations were initially addressed under the IED program. Meanwhile, the consideration of systems use stimulated the Independent Research funded task on minimizing the number of photon-electron interfaces by studying the kinds of initial signal guiding, modulating, splitting, and combining functions that could be performed optically by the processing of solid-state materials.

The luminescent materials programs show again the interaction of researcher, designer, and purchaser. The basic science background knowledge is being applied to produce more flexible phosphors for displays of enhanced flexibility and capability and to free the procurement of phosphors from proprietary, empirical data and base the selection of materials on a reproducible, scientifically-based pertinent measurement program.

*C. P. Huber*  
Code 0200

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# Highlights of FY72

## Integrated Optical Circuits

D. J. Albares

*The basic element in integrated optical circuits is the thin-film optical waveguide. Two FY72 achievements of the NELC investigation into the fabrication processes of waveguide structures in single-crystal semiconductor compounds:*

- 1. Solid-state diffusion of a dopant into a II-VI semiconductor crystal substrate to create a higher-index guiding region.*
- 2. The observation of waveguiding in ZnS and ZnSe films grown by heteroepitaxy on GaAs substrates.*

*The payoff of this technology in future military systems is isolated-terminal, emi-free, redundant, fail-operative information transfer applicable to modular command control and communications.*

The concept of miniature optical components interconnected via optical waveguides on transparent dielectric substrates is attractive from the standpoints of military information transfer and high-capacity (multi-GHz) telecommunications. Optical sources, modulators, detectors, filters, couplers, etc., might be incorporated into "circuits" analogous to integrated electronic circuits which would execute a variety of functions with significant cost-performance advantages.

A great stimulus to integrated optics has been the advent of low-loss ( $< 20$  dB/km), single-mode ( $> 10$  Gbits/sec over a km length) glass fiber waveguides; integrated optics would provide the necessary modulation bandwidth (at higher efficiency) required to match these waveguides. A major interest in integrated optics from a military system standpoint is the potential for implementing a fiber optic transmission line, multi-terminal multiplexing system through low-loss integrated optic coupling and modulation elements. This would offer isolated-terminal, emi-free, redundant, fail-operative information transfer, thus facilitating the truly modular (including distributed computer) command control and communication system.

The potential uses for integrated optics extend beyond communications systems. These circuits are expected to find applications in optical information processors, optical information storage systems, dis-

plays, and entirely new areas stimulated by this technology. This research field is new and dynamic; estimates for realization of devices and systems range from 2 to 5 years.

The Integrated Optics Program at NELC was partly a natural outgrowth of an independent research program conducted in thin-film optics and platelet lasers in FY71. In addition to the scientific findings of the FY72 program, it led directly to the establishment of a broader research program in this field sponsored by the Advanced Research Projects Agency, managed by NELC, and involving both industrial and university laboratories. Furthermore, a program to assess the applicability of integrated optics technology to avionics systems was formulated and undertaken during the year for the Office of Naval Research.

The Independent Research Program in FY72 was aimed at investigating the basic element of integrated optics, the thin-film optical waveguide. Furthermore, attention was directed to single-crystal films for their potential in future electro-optical and nonlinear devices. Consequently, work was done in the fabrication processes and properties of waveguide structures in several single-crystal semiconductor compounds. Two important results have emerged from this work, one being the promising technique of solid-state diffusion of a dopant into a II-VI semiconductor crystal substrate to create a higher-index guiding region and the other being the observation of waveguiding in ZnS and ZnSe films grown by heteroepitaxy on GaAs substrates. The epitaxial process (1) offers the possibility of fabricating, on a single substrate, optical circuits which utilize the favorable properties of both II-VI and III-V materials, and (2) opens new possibilities for future "monolithic" optical circuits.

The dielectric waveguide consists of a region of material of refractive index  $n_1$  bounded by a region with lower refractive index  $n_2$ . In the language of geometrical optics, the rays from the high-index region undergo total internal reflection at the interface for angles greater than the critical angle. Waveguides have been fabricated both in planar (slab) geometry and in channel configurations. Figure 1 illustrates channel guides configured for a coupler, a modulator, and a filter. Dimensions of a single-mode guide for visible light would be  $1 \times 5 \mu\text{m}$  with a 1% change in index. Processes for creating an elevated index include ion exchange, particle bombardment, sputtering, evaporation, diffusion, and epitaxy.

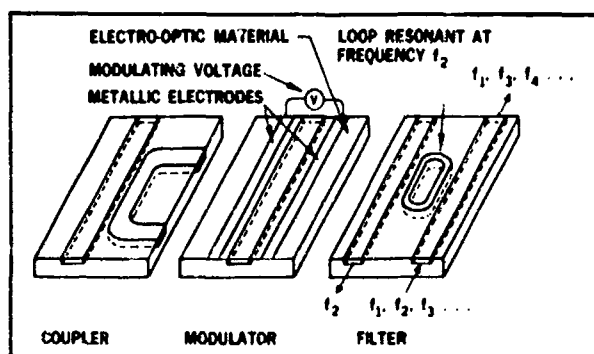


Figure 1. Channel guides configured for a coupler, a modulator, and a filter.

The diffusion approach was investigated using II-VI single-crystal substrates which generally have sizable electro-optic coefficients and low loss to visible and near-infrared radiation. The technique is simple and inexpensive, can produce index changes up to about 5%, and offers inherently smoother "walls," a requisite for reducing losses due to scattering from the guide walls. By diffusing cadmium or selenium into ZnSe, ZnS, and CdS substrates, mixed single-crystal planar waveguides were formed ranging in thickness from 2 to 12 micrometers. Figure 2 illustrates the diffusion steps for fabricating a channel guide and the materials involved. Commercial crystal substrates were used ranging up to about 1 cm in length. In some cases, thermal etching of the surface became serious and was treated effectively by including powdered substrate material in excess of the amount required to establish equilibrium in the diffusion chamber.

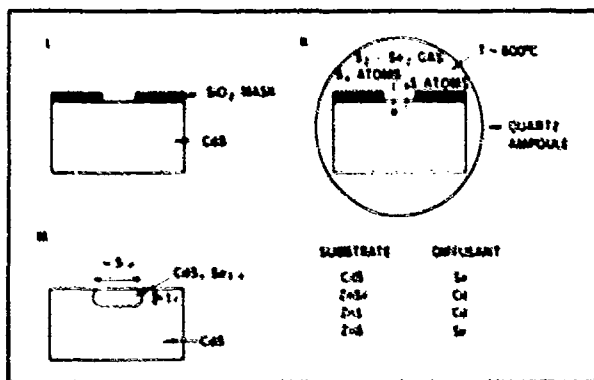


Figure 2. Diffusion steps for fabricating a channel guide.

In these experiments, 6328-Å light was focused onto the cleaved edge of the crystal waveguide film via a

microscope objective. Measurements were made of the light emerging from the opposite edge of the film waveguide to determine its spatial profile and polarization properties. Estimates of total losses were made from the measured incident and emerging intensities. Attenuation in the waveguides was determined from the light scattered out of the guide as a function of distance along the guide, assuming the scattering sources were uniformly distributed. The physical properties of these structures were inferred from fluorescence radiation, from microscopy, and from X-ray powder analysis. Supportive work was performed in the measurement of diffusion parameters, fluorescence, and laser properties of graded-band-gap platelets of the Cd(S,Se) system.

Channel waveguides were produced by shadow-masking the substrates with glass fibers during an SiO evaporation step prior to the diffusions. This resulted in a relatively smooth mask through which the diffusant could pass, forming the channel as illustrated in figure 2. The best results were obtained with cadmium-diffused ZnSe, which exhibited losses less than 3 dB/cm (present limit of resolution for the sample length). Present estimates indicate this figure may be acceptable for devices. Channels 2 micrometers deep and 5 micrometers wide produced single-mode propagation of red light as evidenced by guide dimensions, guide gradients, and the polarization character of the light.

The second approach investigated is that of hetero-epitaxial growth of graded index II-VI compounds on GaAs. It appears to offer the advantages of both materials. In particular, the II-VI features of high-resistivity films, low absorption in the visible and near-IR, good electro-optic coefficients, and potential for diffusion doping could be utilized along with the well-developed technology and the junction source and detector capabilities of the III-V's. This structure is particularly well adapted to applying modulating electric fields to the electro-optic waveguide film, since a potential applied across the high-resistivity film and a low-resistivity GaAs substrate will be concentrated across the film accordingly. A circuit can be envisioned in which the junction sources and detectors are fabricated in the GaAs substrates and these are coupled with II-VI film waveguides where modulation, switching, external coupling, and other functions are performed. Films of ZnSe and of ZnS on GaAs, obtained commercially, have exhibited good optical quality (loss  $\approx$  3 dB/cm).

In summary, the program has established important physical parameters and techniques in fabricating and characterizing optical waveguides, both multimode and single mode, by diffusion doping of II-VI substrates. This approach appears to be a relatively simple, inex-



pensive way to obtain guides in optically active single-crystal structures and is a promising candidate for future device work. Second, planar waveguide films of II-VI compounds grown by heteroepitaxy upon GaAs substrates have been found to have good optical quality. This opens up attractive device aspects using the properties of both types of materials. In both II-VI and II-VI/III-V systems the program has identified important research avenues to be explored. An important one is the investigation of electro-optical phase modulation and deflection in the waveguide region. Another is the more precise characterization of the diffused waveguide region and theoretical interpretation of the propagation behavior, including mode conversion, scattering losses, field distributions, and coupling. This program represents an initial effort in a new and multidisciplinary field with both substantial risks and substantial payoffs; it has opened new avenues of investigation, led to a program in technology and avionics applications evaluation, and stimulated a broader coordinated research effort for the Navy and the Department of Defense.

## PUBLICATIONS

Taylor, H. F., Smiley, V. N., Martin, W. E. and Pawka, S. S., "Fluorescence of Graded-Band-Gap  $\text{CdS}_x\text{Se}_{1-x}$  Crystals Produced by Diffusion," *Physical Review B*, 1467 (1972)

Taylor, H. F., Martin, W. E., Hall, D. B. and Smiley, V. N., "Fabrication of Single-Crystal Semiconductor Optical Waveguides by Solid State Diffusion," *Applied Physics Letters*, 1 August 1972

Martin, W. E. and Hall, D. B., "Diffused Waveguides in II-VI Compounds," *Applied Physics Letters* (to be published)

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(NELC Z162)

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# Fiber Optics Communications

J. F. Bryant

*FY72 was a year of exciting progress in the NELC effort to introduce this promising new technology into Navy and DoD service generally. NELC:*

- Demonstrated the feasibility of fiber optics data transfer systems by developing the NTDS fiber optics cable,
- Conducted tests on fiber bundles to determine the effects of tensile, torsional, and environmental stress,
- Constructed a number of fiber optics systems, both digital and analog,
- Successfully tested a digital fiber optics telemetry system designed for incorporation within an acoustic tow cable,
- Developed an electro-optical fiber optics data transmission system for NAVELEX for precise time and time interval distribution,
- Developed audio and video systems to demonstrate the applicability of information transfer through fiber optics for voice and picture presentation, and
- Conducted a DoD-wide conference of fiber optics communications.

Fiber optics transmission lines have conspicuous advantages over conventional electrical lines:

- There is no em cable radiation
- There is no em cable pickup
- There are no grounding problems, no short circuits
- The lines are smaller in size and lighter in weight for a given bandwidth
- They are heat and fire resistant.

Enthusiastic over the potential for military systems represented by these characteristics, NELC prosecuted a vigorous campaign in FY72 against several of the problems that normally make the introduction of a new technology an extended process—proofs of feasibility, development of specifications, and procurement of materials and components.

The feasibility of fiber optics data transfer systems was demonstrated through the development of the NTDS fiber optics cable (figure 1). The wire cable, containing 32 twisted shielded pairs for data transmission, four twisted shielded pairs for control signals, and nine pairs for spare, can be replaced by two fiber optics bundles, one for data transmission and one for

acknowledging receipt of the data. In the fiber optics replacement cable the electro-optical interface and the electronics for transforming the parallel data output to serial data are contained in the terminal connector.

Figure 2 shows the electro-optical interface: the upper circuit board contains the light-emitting diode source that connects to the fiber bundle on the right. Beneath the transmitter board is the photodiode receiver that detects data acknowledgment. The electro-optical system exceeds the slow NTDS data rate in serial operation.

A second digital fiber optics telemetry system, designed to be incorporated within an acoustic tow cable, was also successfully tested (see Optical Multiplexing).

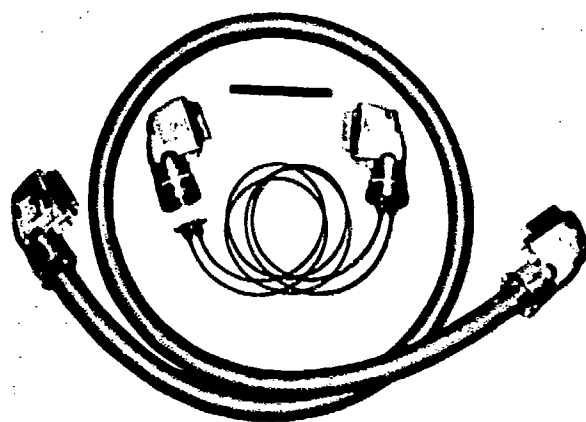


Figure 1. NTDS cables—fiber optics (center) and conventional. Two fiber optics bundles replace 45 twisted shielded pairs.

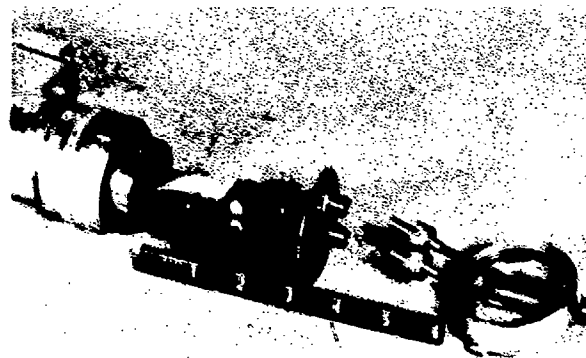


Figure 2. Electro-optical interface. Upper board contains LED source. Photodiode receiver is on underside.

Another application of fiber optics to military systems is precise time and time interval (PTTI) distribution. Under the sponsorship of NAVELEX, an electro-optical fiber optics data transmission system was developed. The demonstration unit is shown in figure 3; electrical input signals are used to modulate the light output of a semiconductor light-emitting diode that is coupled by a fiber optics transmission cable to the receiver. The receiver converts the light pulses into an electrical signal. The unit is capable of handling square-wave pulses up to 10 MHz. The installation of a fiber optics system at a PTTI site in Hawaii is scheduled for FY73.

Audio and video systems were developed to demonstrate the applicability of information transfer through fiber optics for voice and picture presentation. The audio link encodes the linear signals by pulse position modulation of a semiconductor light source for transmission over the fiber optics line, while analog modulation of the source is used for the video link.

A new program to be initiated in FY73 is the suiting out of the A-7 navigation and weapon delivery system with a fiber optics data transfer system. This work is to be sponsored by NAVAIR.

As with any newly developing technology, it is necessary to use the components of older technologies; for example, there are no standard connector or coupling devices as found in the use of wire and coaxial cable transmission systems. Interim use is being made of modifications of BNC, multipin, and specially machined connectors. This points up the need for unification early in the development cycle of components since fiber optics requires that the emitter or detector be placed in close proximity to the end of the fiber bundle to capture the maximum amount of radiation for transmission.

The Center has developed a small repair and splicing kit that will meet the needs of most field users (figure 4). The kit contains all the necessary material for bonding the fiber ends together and grinding and polishing to insure good optical finish. Results with splicing and end termination finishing have been encouraging.

As part of the development of fiber optics technology the Center conducted tests on fiber bundles to determine the effects of tensile, torsional, and environmental stress. Although some tests have been performed by the manufacturers, there is no body of information upon which performance standards can be formulated. It is expected that these tests will be continued to provide data for all branches of the service for design applications and for the writing of military specifications on fiber optics cables.

Realizing the need for cooperation in the development of fiber optics in the military services, the Center

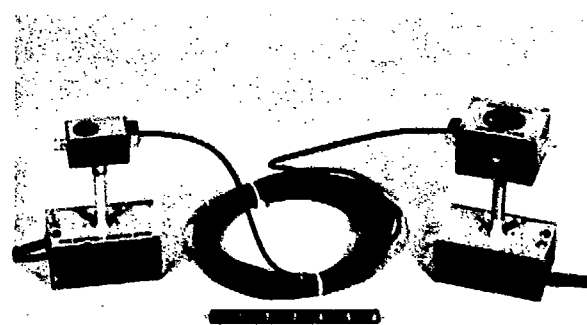


Figure 3. Demonstration data transmission system developed by NELC for NAVELEX for precise time and time interval distribution.

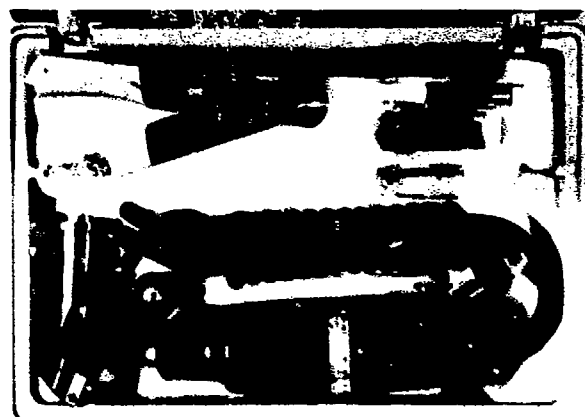


Figure 4. NELC repair and splicing kit.

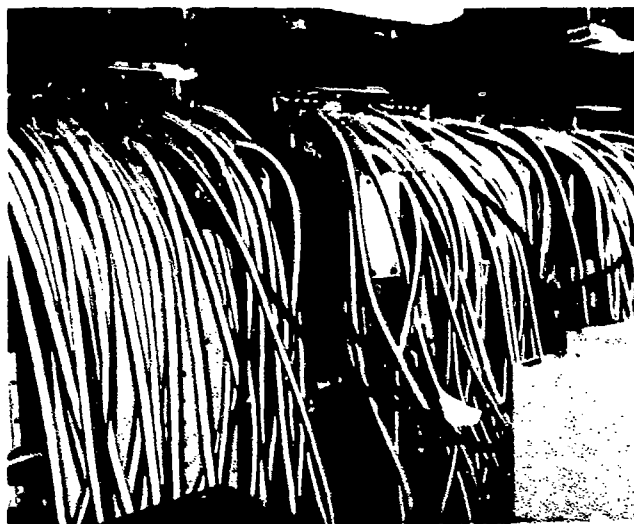
conducted a DoD-wide conference on fiber optics communications in FY72. Representatives from many government agencies met with people from industry working with and manufacturing fiber optic devices and systems to discuss the needs in the development of a technology that could survive in the rigorous environment of military applications. Abstracts of the papers presented were published by NELC Electro-Optics Technology Division. The consensus of the meeting was that many applications could be implemented with existing material, but that many components of the technology need to be developed specifically for fiber optics. Development of low-loss fiber to allow transmission over greater distances is needed as well as components for coupling in and out of data links with a minimum of loss. Development of dual-mode semiconductors that

can emit or detect light pulses is also desirable. Such devices would reduce the number of components needed to construct a data transmit and receive system. Connectors need to be developed for fiber optics bundles for single-bundle and multiple-bundle network applications.

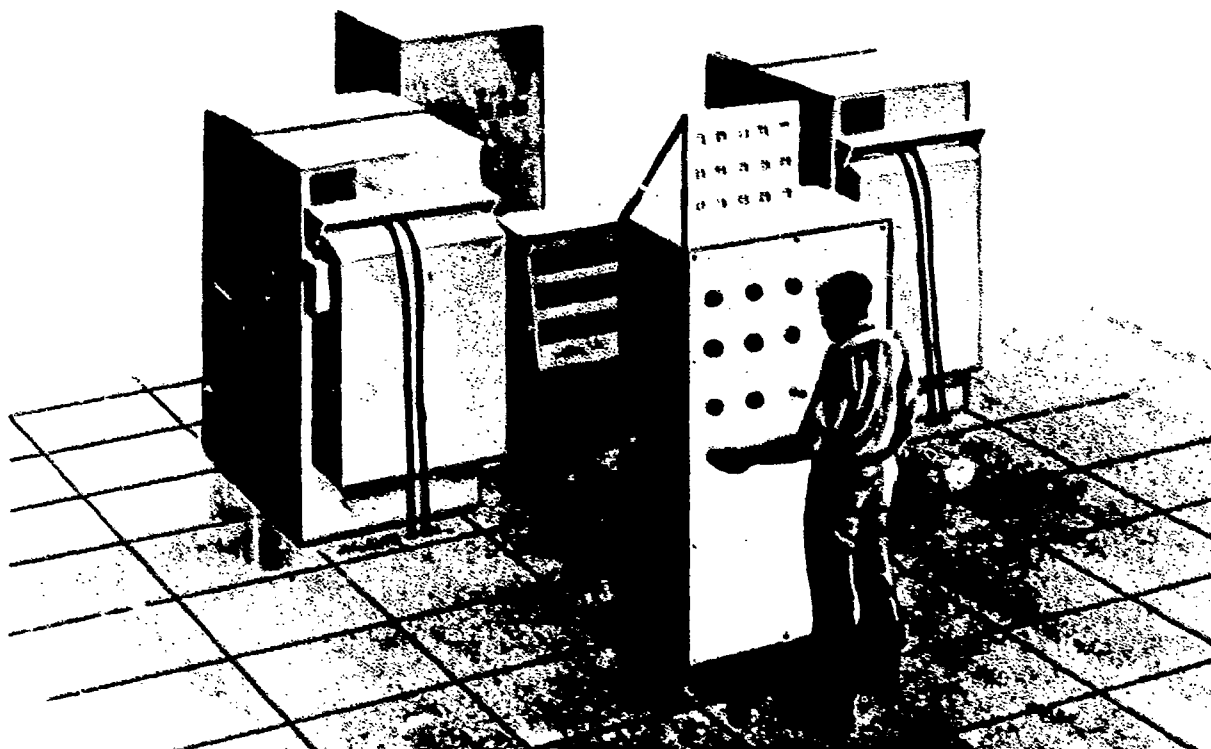
These problems will be dealt with energetically, and it is expected that fiber optics transmission lines will be incorporated into the design of a variety of military systems in the next 1 to 2 years.

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*The photograph presents an example of current practice in equipment interconnects. The drawing emphasizes the mechanical advantages of information transfer via glass fibers. Despite complex and voluminous data flow, interconnection is manageable plus space and weight saving. Not apparent are some other cogent sales points: glass fibers are free of grounding and short-circuit problems; and do not radiate or absorb information electromagnetically, hence are secure.*



# Luminescent and Electronic Materials

H. H. Caspers

*Under the Materials program, NELC explores new concepts and materials for potential applications and evaluates phosphors for application to CRT display.*

*Exploration: Current scrutiny of the unique properties of the rare earths, for example, can lead to the development of voltage-selectable multicolor CRT screens and solid-state lamps which up-convert IR from a light-emitting diode to visible radiation in the green or blue.*

*Evaluation: NELC-developed equipment and procedures simplify a process which conventionally is expensive and complex. The phosphor is deposited onto a conducting glass substrate. The substrate is inserted into a demountable, multisample CRT, where it is induced to simulate the faceplate of a CRT display. Absolute spectral response is determined and converted to a brightness value. This information is then formatted so the CRT engineer can use it effectively in tube design.*

The numerous and innovative applications of luminescent materials in the modern Navy require a continuing effort of this laboratory to keep abreast of new developments and to expedite their early introduction into new and existing systems. These materials have made possible wide-ranging improvements in the areas of command control display technology, infrared-to-visible image conversion, sensor development, and solid-state lasers. New developments in luminescent materials are constantly being explored for potential improvements in existing applications or for the design and implementation of new applications.

A group of scientists at NELC has been involved in a materials program which consists of two major subtasks. One is the evaluation of new and existing phosphors for applications to cathode-ray-tube (CRT) displays such as radar indicators, electronic test equipment, and video image display. The other is the exploration of new concepts and new materials for possible new applications. This effort has examined such diverse materials as rare-earth phosphors in oxygen-dominated host materials, infrared-to-visible up-conversion materials, and thin-film photoconductors for applications to image conversion, liquid-crystal displays, light valves, and optical processing devices.

## PHOSPHOR EVALUATION PROGRAM

The purpose of the phosphor evaluation program is to characterize new and existing phosphors by unique physical parameters which serve as criteria for the acceptability, efficiency, and suitability of particular phosphors for given applications or for the design of new equipment.

One of the important measurements is the determination of the spectral irradiance of cathodoluminescent phosphors under certain conditions of CRT current density, accelerating potential, and method of deposition. The spectral irradiance is a measure of the absolute intensity of the phosphor emission as a function of spectral wavelength. These measurements provide important information for the improvement of phosphors, since these can be more readily associated with the physical processes and energy conversion mechanisms involved within the materials. On the other hand, spectral irradiance data may be transformed to quantities more meaningful to human observers and engineering applications by weighting irradiance values with the spectral response of the "normal" human eye.

To facilitate the aforementioned measurements, a demountable, multisample CRT was built into an existing commercial high-vacuum system. The apparatus consists of a vertically mounted electron gun capable of operating to 25 kV and 1 milliampere. Space is provided for evaluation of up to four samples simultaneously. This instrument is schematically depicted in figure 1.

Phosphors are compared to a secondary irradiance standard to determine absolute spectral responses.

Figure 2 is an example of spectral irradiance data recorded as described herein. These data are converted to brightness or radiance values by standard photometric conversion techniques.

Suitable phosphor materials are deposited by solution-settling onto conducting borosilicate glass substrates. When air-dried and inserted in the demountable CRT, they form the anode of the CRT and simulate the faceplate of a conventional CRT display device. Phosphor materials may therefore be readily and inexpensively compared.

Among subtasks contributing to the solution of technical, fleet-oriented problems is the development of bicolor, dual-persistence phosphors for tactical data display consoles. These phosphors provide selectivity to the console operator, who may require a long-persistence radar mode or a medium-persistence video mode in the same single-gun CRT. The two-color property enables selection of phosphor persistence by the use of optical filters. The spectral properties of one such in-house formulation are shown in figure 3.

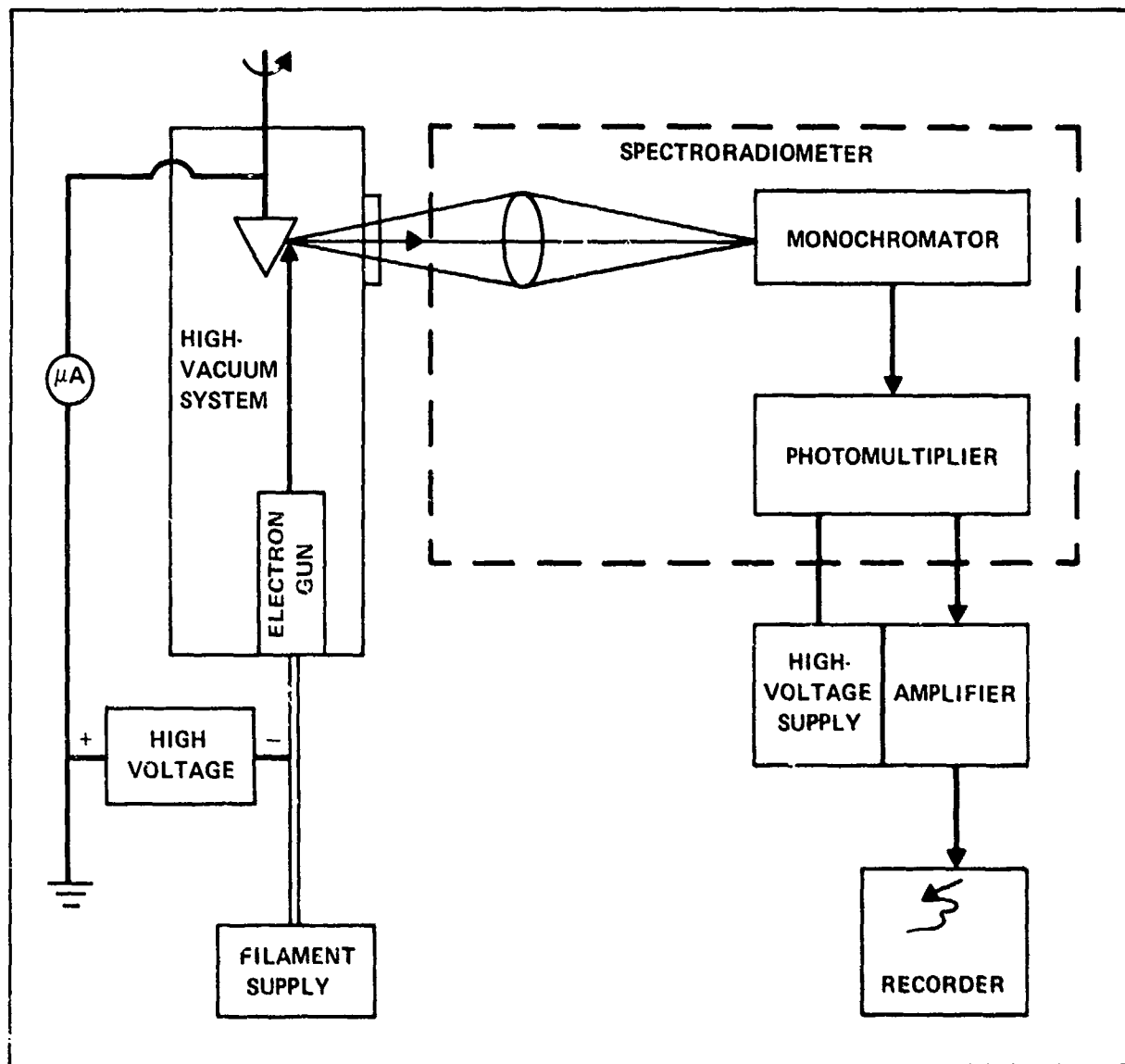


Figure 1. Demountable CRT and spectroradiometer.

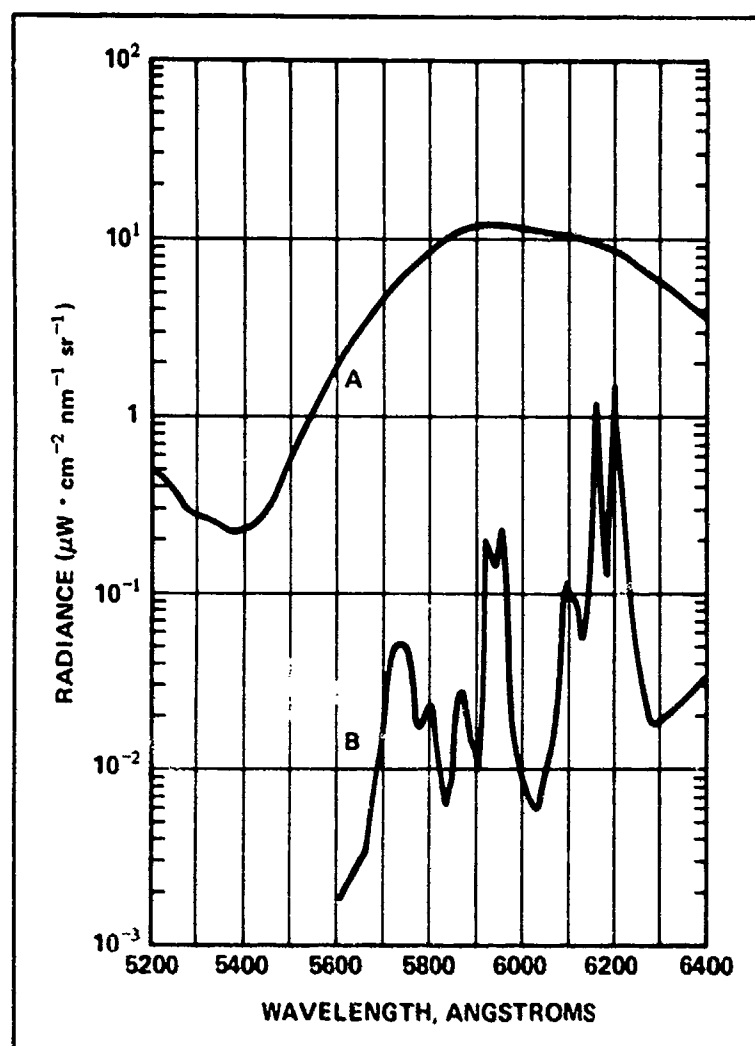


Figure 2. Spectral radiance from two phosphor materials at 20-kV potential and approximately  $1\text{-}\mu\text{A}/\text{cm}^2$  current density for: (A) P19 phosphor powder screen, and (B)  $\text{Eu}^{3+}$  in  $\text{YVO}_4$  single crystal.

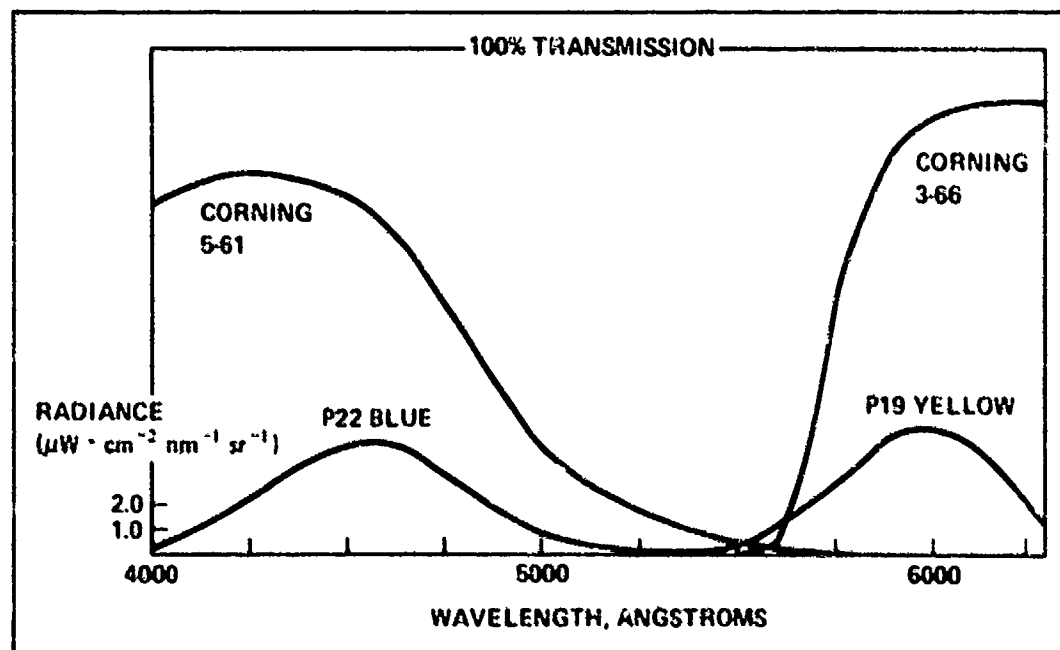


Figure 3. Dual-persistence phosphor-filter combination.

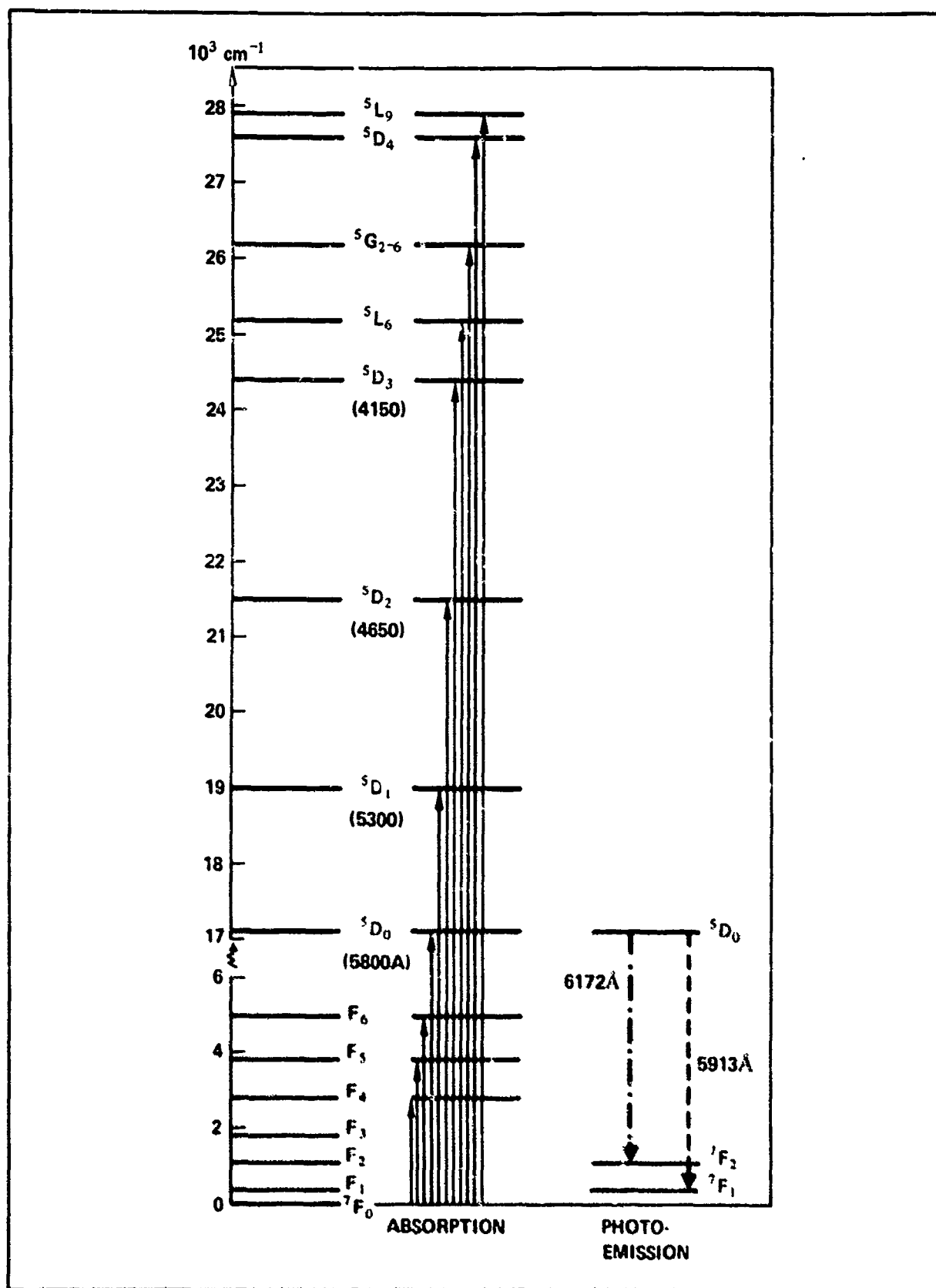


Figure 4. Emission and absorption of  $\beta\text{-Gd}_2(\text{MoO}_4)_3: \text{Eu}$ .



## NEW PHOSPHOR MATERIALS

Recent applications of the unique luminescent properties of rare-earth materials suggest possible wide-ranging and novel improvements in display technology. For example, voltage-selectable multicolor CRT screens have been devised recently. Other examples include solid-state lamps which up-convert infrared radiation from a light-emitting diode into visible radiation in the green or blue. Such applications depend on the unusually narrow electronic energy levels in rare-earth salts, and these applications have begun to accelerate.

Results of research on these materials have shown that oxygen-dominated compounds, nonhygroscopic halides, and oxysulfides of rare-earth elements form compounds that are highly efficient for cathodoluminescence and up-conversion applications. Among these compounds are rare-earth molybdates and isostructural compounds.<sup>1,2</sup> The group at NELC has been investigating and characterizing the electronic properties of pure  $\beta\text{-Gd}_2(\text{MoO}_4)_3$ , of various rare-earth activated gadolinium compounds such as  $\beta\text{-Gd}_2(\text{MoO}_4)_3:\text{Eu}$ , and of various sensitized and activated compounds for application in infrared-to-visible conversion schemes. The infrared-to-visible conversion experiments were performed on  $\text{Gd}_2(\text{MoO}_4)_3:\text{Yb, Er}$ ;  $\text{Gd}_2(\text{MoO}_4)_3:\text{Yb, Ho}$ ; and  $\text{Gd}_2(\text{MoO}_4)_3:\text{Yb, Tm}$ .

1. The results on  $\beta\text{Gd}_2(\text{MoO}_4)_3$  revealed it to be an excellent host material for rare-earth activation in the range of 3000-50000 Å. The observed ultraviolet absorptions at 3000 Å were identified as the  $^8\text{S}_{7/2} \rightarrow ^6\text{P}_{7/2, 5/2, 3/2}$  transitions. The intense infrared absorptions beyond 5  $\mu\text{m}$  are due, possibly, to a number of effects, one being the strong electronic and vibrational absorptions of the  $(\text{MoO}_4)^{-3}$  complex.
2. Figure 4 shows the results of the characterization of the electronic properties of activated  $\text{Gd}_2(\text{MoO}_4)_3$  with  $\text{Eu}^{3+}$ . The intense group of narrow emission lines at 6100 and 5900 Å observed under ultraviolet excitation corresponds to transitions originating from  $^5\text{D}_0$  to  $^3\text{F}_{2,1}$  states, respectively. The cathodoluminescence of this compound will be examined under 25-kV excitation and compared with the observed bright red cathodoluminescent spectrum of  $\text{YVO}_4:\text{Eu}^{3+}$ .

3. Infrared-to-visible experiments were performed on sensitized and activated gadolinium molybdates containing (Yb, Er); (Yb, Ho); (Yb, Tm). Gallium arsenide diode infrared emission in the range 9200-9600 Å was used as the pumping radiation and converted to visible light by the co-doped rare-earth phosphors. The samples containing (Yb, Er) converted infrared to green light while the (Yb, Ho) combination converted IR to red light. No blue emission resulted from the  $\text{Gd}_2(\text{MoO}_4)_3:\text{Yb, Tm}$ .

4. The detailed characterization of  $\text{Pr}^{3+}$  in the quantum electronic host material  $\text{LiYF}_4$  has been completed and is being prepared for publication (ref. 3).
5. A new program has been initiated dealing with the optical and electrical properties of wide-bandgap II-VI semiconductors. Renewed interest in these compounds has resulted from the recent successes of:
  - a. Ac and dc electroluminescence of II-VI powders and films containing Mn and Cu activators for applications to large panel displays.
  - b. The use of photoactivated liquid-crystal light valves and the use of CdS and ZnS photoconductors in connection with nematic/cholesteric liquid-crystal cells for their storage capability and optical processing applications.

Efforts have begun in sputtering and evaporation of II-VI photoconductive materials for their use in electroluminescence and liquid-crystal cell applications.

## REFERENCES

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ZRC 0.01.01  
(NELC 2163)

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225-6591



*The operator in this artist's conception of a future command control display is using historical information, shown in red on the CRT, to evaluate current sensor information, shown in blue. The short-persisting blue tracks represent the immediate locations of live targets – ships, planes, and missiles. The long-persisting red tracks, fading with time, show where the targets have been over the preceding several minutes, thus establishing course and speed and thereby enabling target identification. The compressed tracks are ships; the most spread-out tracks are missiles.*

*Timely realization of these capabilities within the Fleet may depend heavily on contributions from any number of the IR/IED programs discussed in this publication.*

# Sponsored Programs Based on IR/IED-Initiated Work

(Only programs not listed in FY71 report are listed here.)

<i>Funding</i>	<i>NELC No.</i>	<i>Title</i>	<i>Based on</i>
<b>OPTICAL TECHNOLOGY AND APPLICATIONS</b>			
1. 6 21 05D ARPA S49-156 B403	Blue-Green Omega Mass Transport Dye Laser Transmitter Development	ZR011-01-01 (NELC Z160)	
2. 6 27 52N XF14-222-014 F211	Dye Development for Lasers	ZFXX-512 (NELC Z212)	
3. 6 11 51N RR014-11-04 F212	Integrated Optical Circuits in Avionics Systems	ZR021-03 (NELC Z162)	
4. 6 11 01D ARPA P2D10 F215	Integrated Optical Circuit Techniques	ZR021-03 (NELC Z162)	
5. 6 36 07N U17-54 F216	Fiber Optic Control Data Link	ZFXX-212 (NELC Z246)	
<b>MATERIAL SCIENCES</b>			
6. 6 23 01D ARPA P2E90 T302	Very Low Transmittance Measurements of Solids and others	ZR011-01-01 (NELC Z156)	
<b>ELECTROMAGNETIC PROPAGATION</b>			
7. 6 27 24H DNA HD028 M213	Investigation of Atmospheric Dynamics in the D-Region	ZR021-01 (NELC Z135)	
<b>SIGNAL AND INFORMATION PROCESSING</b>			
8. 6 27 20N XF14-222-018 B811	Detection of Covert Communications	ZFXX-212 (NELC Z222)	
<b>MAN-MACHINE EFFECTIVENESS</b>			
9. 6 37 71N BUMED M43-05 S101	Visual Electrophysiological Recording System	ZF011-01-01 (NELC Z150)	
<b>MICROELECTRONICS AND APPLICATIONS</b>			
10. 6 27 55N UF00-342-405 R503	Microelectronics Radiation Resistance UF00-545-401	ZR011-01-01 (NELC Z159)	
11. 6 27 55N XF52-545-017 R134	Solid State Reliability	ZFXX-512 (NELC Z229)	
12. 6 27 15N WF00-545-606 R210	Elastic Transfer Power Supply Analysis	ZFXX-512 (NELC Z251)	

# Summaries of Independent Research Projects

## Lower Ionospheric Physics

### INTRODUCTION

Accurate forecasts of vlf/elf broadcast coverage are needed for operational fleet commanders and for determining emergency network design parameters. The purpose of this program is to establish the feasibility of obtaining data on which the forecasts can be based via a net of inexpensive vlf sounders or special monitors located near the Omega Navigation System transmitters.

Numerical methods are available for calculating vlf and elf communications coverage and performance characteristics given accurate descriptions of the electron-density and collision-frequency profiles in the lower ionosphere. The usual hf radio and rocket sounding techniques fail to provide this information because of the low electron and high neutral particle densities of the region. NELC has pioneered an approach to obtain the required data from steep-incidence vlf radio-sounding measurements. Full-wave methods are applied to an adjustable model of the ionosphere to obtain reflection coefficients or waveguide mode parameters. The ionospheric parameters are automatically adjusted until differences between calculated and measured data are minimal, at which juncture the ionospheric parameters of the model are near coincidence with the real ionosphere at the time the measured data were taken.

### PROGRESS DURING FY72

Several approaches for obtaining D-region electron densities from vlf and elf data are being evaluated simultaneously. Differences lie principally in the functional forms which describe the ionospheric profile, the numerical methods used to determine the adjustment direction and step size, the assessment of error, etc.

One approach allows a choice of exponential seg-

ments, a combination of exponential segments and parabolic layers, or a Chebyshev polynomial representation of the natural log of electron density to describe the electron-density profile. Of these the Chebyshev polynomial appears most useful. The measure of departure between measured and calculated data has been expanded to include, along with sums of squares of differences between measured and calculated data, terms derived from first- and second-order differences in changes of reflection coefficients with frequency. A study of optimum starting profiles has given inconclusive results. Starting profiles near the correct solution sometimes require more steps for optimization than starting profiles far from the correct solution.

A promising new approach growing out of a method developed in FY71 not only treats minimization of differences between measured and calculated data but also constrains the ionospheric profile by requiring the second-order curvature of the profile to be minimal. The method also much expedites the profile adjustment technique by starting the search with an exponential profile and gradually incrementing a constraint parameter so that adjustment steps always tend toward minimization. The technique has been used to obtain both the electron-density profile and collision-frequency profile from NELC vlf sounder data. If some limits to the accuracy of the measured data are known, error limits on the best-fit electron-density profile are also obtained.

One extremely promising new formulation uses measured values of field strength at a number of positions distant from a vlf or elf transmitter or spherics source as the independent data. After these data are related to waveguide mode parameters, which are in turn related to the ionospheric profiles of electron density and collision frequency, the minimization process is applied to obtain the sought-after electron-density profiles. In view of the wealth of long-path vlf data, this approach has tremendous potential.

## PUBLICATIONS

### IN-HOUSE PUBLICATIONS

Hill, J. R., *A Method for Rapid Computations of VLF, Steep-Incidence Reflections from the Ionospheric D-Region*, NELC Technical Report 1784 19 August 1971

Shellman, C. H., *A Profile Inversion Method Applied to Finding D-Region Electron Densities from VLF Reflection Data*, NELC Technical Note 2030 3 May 1972

### WORKSHOP PROCEEDINGS

Shellman, C. H., "The Inversion of VLF/LF Sounder

Data to Obtain D-Region Electron-Density Distributions," to be published in "Proceedings of a Workshop on the Mathematics of Profile Inversion (Ames Research Center, July 1971)," edited by L. Colin, NASA TMX-6 2150, 1972

ZR000.01.01  
(NELC Z135)

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225-7677

# Digital Systems: Walsh Function Theory and Application to Design of Naval Equipment

The effort under problem Z155 has been focused on using Walsh analysis, in combination with other techniques, to reduce the volume of digital data required to store and transfer graphical information, and to use Walsh functions in the analysis and enhancement of images of interest to the Navy. Walsh analysis is similar in some aspects to Fourier analysis.

The Walsh functions form a complete orthogonal set, and assume only the values +1 and -1. Any reasonable function can be represented as a weighted sum of Walsh functions, and the Walsh transformation can be readily performed through sampling, additions, and subtractions. This latter feature enables hardware implementation via switching and summation networks. Two preliminary designs for a Walsh transform device were done by C. Nuese, Decision and Control Technology Division. The two designs compared serial versus parallel approaches.

Computer programs were written which numerically evaluate Walsh functions and compute the Walsh transform of a sampled function. These codes are general in nature, and both the codes and their usage are described in NELC TN 1986. Since the Walsh transform does not require multiplications, it enjoys a substantial speed advantage over the Fourier transform. This speed advantage makes it a practical tool in image processing and enhancement.

A program for simulating encoding schemes for a digitized image was written for the NELC IBM computer. The reconstructed image is "displayed" via the line printer. By encoding a digitized image with the Walsh transform, one can use the inherent correlation between picture elements to obtain data reduction. Although pictures displayed this way are crude, the method shows promise. In this program, data reduction was obtained by deleting 50% of the transform coefficients. The reconstructed images were subjectively judged acceptable.

We have identified a use of this technique in an ongoing NELC problem—still-frame TV transmission. A follow-on problem to Z155 will incorporate the Walsh transform encoder in this TV system. To further investigate both this type of source encoding and image enhancement techniques, an experimental system will be developed. The system will be capable of digitizing an image, recording the resulting digits onto magnetic tape (for use in simulating the encoding schemes on a general-purpose computer), and, finally, playing back the reconstructed image over a TV monitor. This system will enable an optimal encoding scheme to be designed.

## PUBLICATIONS

McCall, D. C., *Computer Programs for Walsh Analysis*, NELC Technical Note 1986 6 Jan 1972

McCall, D. C., *A Walsh Transform Source Encoding Technique for Bandwidth Reduction* NELC Technical Note (in preparation)

ZROOO.01.01  
(NELC Z155)

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225-6257

# Compatible MOS/LSI and Acoustic Surface-Wave Technologies

Current investigation is aimed at developing a technological base for the development of integrated surface-wave MOS devices for applications requiring programmable filters and delay lines.

The integration of the electronic and wave-propagation processing into a single substrate is the approach used to (1) solve the problem of reliability caused by the large number of leads; and (2) provide a fully programmable quadriphase surface-wave filter which can be matched quickly to any desired waveform and therefore achieve a rapid code-changing capability without the necessity of modifying one metallization pattern to another. These capabilities will simplify the design of naval radar and communication subsystems and endow them with new flexibility.

The implementation of a programmable device is based on the concept that phase and displacement are equivalent. The sensors in each acoustic path (see drawing) are positioned to give one of the ( $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ ,  $270^\circ$ ) phases with reference to the center transducer (IDT).

The piezoresistance of inversion layers in silicon MOS structures can be used to detect surface waves. An elongated MOS device, oriented on a specified crystal plane and a specified wave-vector direction, has been designed and is used as sensor to fabricate a 16-bit, three-cycle/bit programmable, quadriphase correlator at 70-MHz central frequency and bit rate of 5 MHz. The quadriphase concept requires four sensors/bit, each of which is individually switchable for maximum programmability. Because the wavelength associated with a 70-MHz wave ( $\lambda \sim 1.7$ -1.8 mil) is smaller than any MOS structure (2.7 mils) which can be accommodated by the state-of-the-art semiconductor technology, the central frequency is reduced to 45 MHz and a multiple acoustic path is implemented with a thin-film ZnO transducer (generator of acoustic surface wave) which is placed in the center of the matched filter array (see drawing).

The selected geometry for the MOSFET sensor is well suited for surface-wave detection since (a) current flow is limited to the surface inversion layer region having a thickness  $< 100 \text{ \AA}$ , whereby effective interaction with the energy content of the wave is realized and (b) the device can be fabricated with channel length less than  $\lambda/2$  for waves in silicon of frequencies less than 100 MHz.

The theoretical prediction, design trade-offs, and logic design of the 16-bit programmable quadriphase correlator have been completed. The MOSFET "approach" is preferred to the hybrid, more conventional one, which consists of a standard piezoelectric tapped delay line with rf bonding leads connected to a switching and logic chip. Besides eliminating problems of isolation and crosstalk, the "silicon" approach insures reliability and producibility; the gate voltage control is obtained from a static shift register/ROM which is built on an adjacent portion of the chip. The ROM provides the series of coding sequences needed for programmability. The logic design is complete, the chip layout is ready for implementation, and the experimental processing results will be available by October 1972.

As a result of the present investigation, the quadriphase-programmable concept has generated interest in NAVSEC. At their request, the design and fabrication of a 127-bit, programmable 60-MHz correlator will eventually be funded for incorporation in "Aegis."

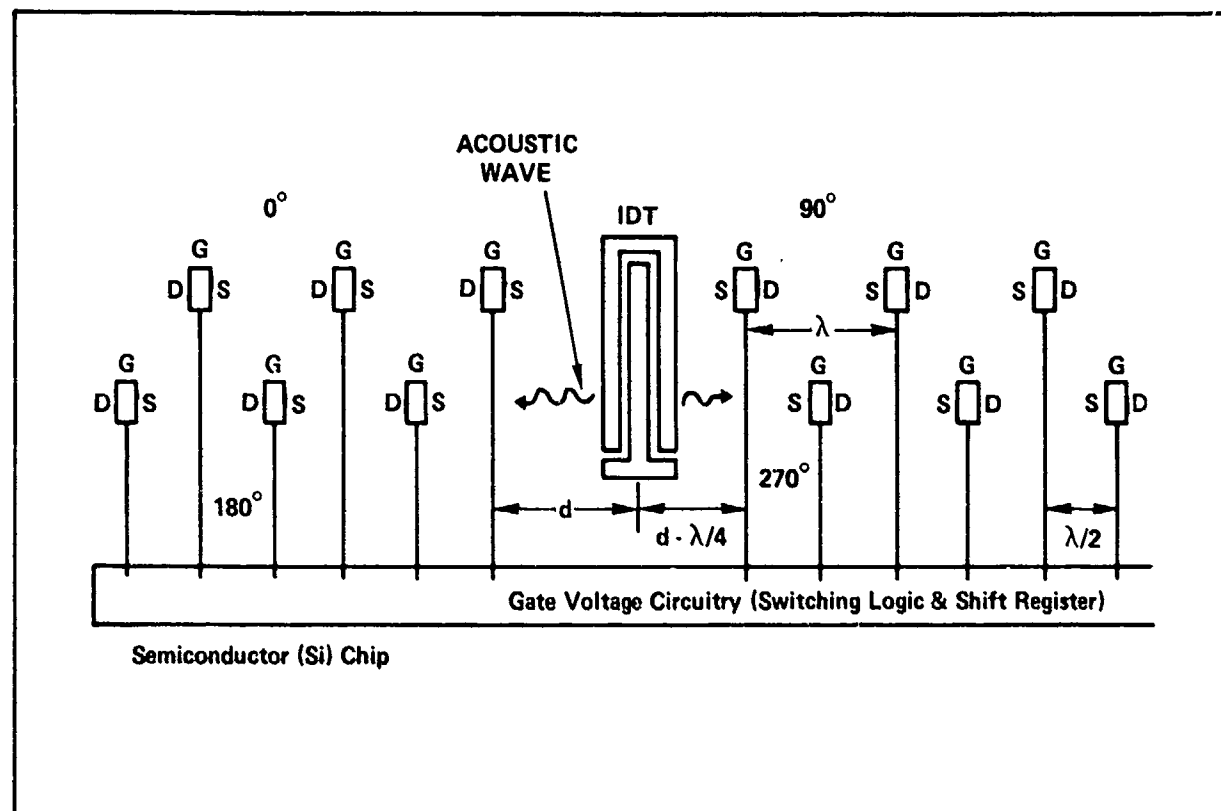
The correlator will be built in cooperation with industry. Completion is scheduled for September 1972.

## PUBLICATIONS

An NELC technical document will report the results achieved after the chip fabrication. It will also discuss the operational implications of this technology to some naval systems.

ZR000.01.01  
(NELC Z165)

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225-6877





# Tunable Spin-Flip Raman Laser

Current communication systems using microwave frequencies do not have sufficient spatial resolution to prevent interception of a "secure" transmission. The objective of this program is to provide a method for restricting communication to the intended receiver only. A spin-flip Raman laser (SFRL) is under development to provide continuously tunable, coherent radiation in the spectral ranges of 5 to 6  $\mu\text{m}$  and 9 to 14  $\mu\text{m}$  for use as a major component in a tunable laser transmitter. The newly discovered process which makes tuning feasible is being applied for the first time to optical communications at NELC, and could be incorporated in future versions of OCCULT. The main components of the SFRL and progress toward developing them are outlined below.

A fixed-frequency pump laser is used to generate stimulated Raman scattering in a semiconductor which is shaped as an optical resonator. The frequency of the Raman-scattered radiation depends on an applied magnetic field according to the relation

$$\omega_S = \omega_L - g\beta H$$

where  $\omega_S$  is the scattered frequency,  $\omega_L$  is the pump frequency,  $g$  is the effective electron g-factor,  $\beta$  is the Bohr magneton, and  $H$  is the magnetic field.

A pump laser has been constructed and operated cw single frequency with either  $\text{CO}_2$  or CO as the active gas. Provision must be made for Q-switching the  $\text{CO}_2$

laser on a single transition to pump InSb as the scattering sample in the range 9 to 11  $\mu\text{m}$ .

At present, we shall continue to operate the laser cw with CO as the active gas. This is preferred for the initial operation of the SFRL with InSb because the threshold pumping power is about 1 W cw with a magnetic field of about 10 kG. This is within the range of the available magnet.

A sample of InSb has been cut and polished to form a Raman resonator. The electron concentration is about  $10^{15} \text{ cm}^{-3}$  at 77 K. This type of material was shown to require the lowest magnetic field for SFRL operation when pumped at 5.3  $\mu\text{m}$ . The sample is held in a cold finger which mounts in the coil of a superconducting magnet and maintains the temperature of the sample below 20 K.

The superconducting magnet has operated at fields up to 20 kG. This field strength is adequate for pumping InSb at 5.3  $\mu\text{m}$  but not at 10.6  $\mu\text{m}$ . Although high magnetic fields are not necessary for InSb SFRL pumped at 5.3  $\mu\text{m}$ , it is convenient to use a superconducting magnet because of the requirement for low temperatures.

The above components have been tested and are being assembled for operation together.

ZR000.01.01  
(NELC Z164)

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## Natural Language Development

An inexperienced technician discovers a malfunctioning electronic equipment. He addresses the computer, and tells it, in his own dialect and jargon, which equipment is in trouble. The computer asks questions of the technician: "What happens when probes are placed at 'A' and 'B' and a scope reading is taken?" The technician describes the reading to the computer, which deduces that it is normal or abnormal and then infers the next step to take, on the basis of the reading and stored procedures. When the problem is isolated, the computer searches a data base of parts required to fix the malfunction and guides the technician through repair procedures.

This episode illustrates a conceivable situation in which human maintenance of electronic systems is guided completely by computer, and communication both ways between man and computer occurs as naturally as communication between two humans - via conversation.

The human member of the team in this situation requires little programming. His technical training may be of lower level, and he may have had no computer training whatever - beyond an "introduction" to the machine. The computer, however, along with extensive banks of stored data, must have understanding of an order not yet available.

Research to date has emphasized, first, the development of a standard query language for Navy command control data management systems - specifically, natural English - and, second, data structure and formal representation of meaning. The first task has been to familiarize Center researchers with the state of the art in natural language communication with computers. Four research projects have been reviewed in depth via literature review, personal contact with principal investigators, and, in one case, actual installation on the Center's IBM 360/65.

The first studies have shown that in most natural language systems a great deal of attention is paid to careful construction of syntactical rules obeying good English structure. There has been little refinement of these rules through actual full-scale usage. There is, in general, no allowance for colloquialism of usage. Future research with FY73 NELC internal research funding will be designed to explore the problem of Navy command control colloquialism.

Studies have also shown that formal representation in the computer of the meaning contained in natural language is not well understood. For instance, most data management systems in wide use today can retrieve explicitly stored information rapidly and efficiently. These systems also allow update of such facts. In the formal representation of the predicate calculus, for example, the latter corresponds to the concept "there exists," and questions are asked about "what exists?" It is reasonable to expect that a candidate formalism for meaning (a semantic system) will be able to understand and properly process problems of inference and deduction. For example, suppose a data management system is told that all Navy ships in San Diego are part of the Seventh Fleet, except for USS PROVIDENCE. This statement implies the semantics must understand the concept of the quantifier "all" as well as "there exists." Later a new Navy vessel arrives in San Diego and the question is asked "is that vessel a part of the Seventh Fleet?" Intuitively, the answer should be "most likely, but remember USS PROVIDENCE." Programs which can prove theorems in a formal deductive logic system are the first steps toward solving this problem. However, conclusions drawn from proof of theorems must be irrefutable. Such a conclusion cannot be drawn in the previous example.

Questions also arise as to how to introduce new meaning to a system in a natural manner. One should be able to just say "USS NEVERSAIL has arrived in San Diego" for the system to understand: (1) that USS NEVERSAIL is a Navy ship (because of the way it is named) and (2) that it is now in San Diego, although it has never heard of USS NEVERSAIL before. Answering questions about data contained in "informal" text - i.e., Naval messages, directives, etc. - is also a problem in semantic systems which is not well understood. This research will identify semantic descriptions, inference techniques, and ways of extending meaning in the system naturally which are necessary to handle a broader class of Navy command control problems than today's systems can address.

This Z problem will, in FY73, address two aspects of the natural language development problem. The first is the problem of colloquialism of usage and the second the representation of meaning and data structure. Funding on the problem of colloquialism is also being requested from the Information Systems Program of the Office of Naval Research. To date there has been no word from them as to acceptance of our proposal. G. Goldstein of that office was at NELC to review our project on 6-7 July.

## **PUBLICATIONS**

It is expected that a technical note describing results of (1) experimentation with colloquialism of usage of natural language computer systems and (2) a detailed review of data structures and representations such as have been proposed in state-of-the-art natural language systems will be published no later than 1 January 1973.

**ZR000.01.01**  
**(NELC Z166)**

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# Liquid Crystal Display Techniques

The purpose of this task was to do applied research in the use of liquid crystal technology for display purposes, gather appropriate critical performance data, and exercise experimental liquid crystal display cells in a real-life large-screen display environment.

This involved the investigation and survey of liquid crystal literature, materials, and devices, including on-site survey of leading industrial technology, and the exploratory application of state-of-the-art liquid crystal cells.

Liquid crystals are chemicals with properties which make them appear both crystalline and liquid at certain temperature ranges. Some of the properties are optical birefringence, circular dichroism, light scattering, other optical activities, and electric and magnetic properties.

Liquid crystals are presently subdivided into three distinct classes—nematic, cholesteric, and smectic. Of the three, nematic and cholesteric are at present the most interesting and promising for display application. For example, nematic liquid crystals generally exhibit optical properties which cause them to change from a clear transparent to a diffuse state when a voltage is applied across them. With cholesteric liquid crystals, they have the unusual property of scattering light of various colors over a specific temperature range.

Experimental results showed that liquid crystal cells have great potential for application in projection large-screen displays and displays in general. Photoactivated liquid crystal cell experiments showed visual and photometric qualities from poor to very good depending on liquid crystal composition, cell construction, test setups, and mode of testing. In general, appearance, resolution, contrast, and brightness uniformity were satisfactory. Some of the liquid crystal cells showed contrast ratios of 5:1 or more with resolutions of better than 20 line pairs per millimeter at a screen brightness of about 10 foot-lamberts. Typically, photoactivated liquid crystal display cells required about 300  $\mu\text{W}/\text{cm}^2$  of activating light and about 20 Vdc to write.

It was determined that an optical system designed and optimized specifically for use with liquid crystals would greatly enhance picture quality over that observed with the existing optical projection setup. This is due to the

phenomenon of light scattering utilized in liquid crystals vice light absorption utilized in conventional imaging systems.

Liquid crystal cell configurations also show promise as variable-persistence displays, real-time operating light valves, color filters, variable light attenuators, etc. Ultimately, liquid crystals may permit the development of wall-type displays with presentation in color. Benefits from liquid crystals will be realized in reliability, space, weight, power, and cost.

In terms of Navy use of this technology it is recommended that exploratory development of liquid crystal display cells be carried on; that photoactivated liquid crystal work be directed toward projection large-screen displays where improved capability and flexibility are apparent; that matrix-addressed liquid crystal display cells be developed for use as chart slides and real-time annotation; that lifetime experiments on various liquid crystal cells be conducted; and that a prototype liquid crystal projection display unit for interface with ship-board type OA-8393 Large-Screen Projection Display at NELC be developed.

Exploratory development of liquid crystals for use in large-screen projection displays is planned for FY73 under NAVSHIPS support.

## PUBLICATIONS

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Heilmeyer, G. H., *Liquid-Crystal Display Devices*, *Scientific American*, p. 100-106, April 1970

Margerum, J. D., Nimoy, J., and Wong, S. Y., "Reversible Ultraviolet Imaging With Liquid Crystals," *Applied Physics Letters*, v. 17, no. 2, 15 July 1970

Baltzer, D. H., "Nematic Crystals Come of Age," *Electro-Optical Systems Design*, p. 72-77, January 1970

ZR000.01.01  
(NELC Z168)

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225-7047

# Diagnosis of Color Anomalies by Means of the Evoked Cortical Potential

The aim was to find whether recordings of the electrical activity of the visual system could be used to sort out the color-weak and color-blind.

Earlier work had produced conflicting results. The waveforms recorded by different researchers varied with size of stimulus, brightness of flash, rate of flashing, angle of viewing, presence of sharp edges or contours in the visual field, background lighting, attention, motivation, and other factors.

NELC wanted waveforms that varied specifically with color. More than 40 subjects with normal color vision were selected and subjected to a flashing light of different colors. Recordings were made at the eyes (ERG--electroretinogram) and at the surface of the scalp over the visual portion of the brain (VECP--visually evoked cortical potential). Computer averaging was used to eliminate noise from the recordings.

The differences in response were at first not marked. Evidently the visual system under these circumstances responded chiefly to form and only secondarily to color, so the subjects were provided with goggles with frosted lenses to blur their perception of form, and again subjected to the flashing light. The frequencies of flashing found to produce the most reliable ERG's and VECP's 1 and 6 Hz were used. This time marked differences were obtained.

The ERG's were markedly different for different colors, and all subjects with normal color vision showed the same differential response.

The VECP's were also different for different colors, but the subjects showed equivalent response only to red.

The responses to red of two of the subjects were unlike those of the majority. Conventional testing for color-weakness showed these subjects both to be color-weak--a condition they had not suspected before the testing.

A red-blind subject was tested. ERG and VECP for colors other than red could not be distinguished from those of normal subjects--but differed greatly for red.

We are not yet certain that we have found the conditions which will give us the best chance of identifying color-weak individuals. More research is required to improve the technique. But we now know that we can identify at least some individuals who are color-blind or color-weak by means of their brain waves.

## EXTENSION OF WORK FOR FY73

As part of the color research, a background light was occasionally used to try to increase the differences between the responses to different colors. The results suggested that rod and cone interactions were present in both the ERG and the VECP over a wide range of background illumination. A systematic investigation will be made of the effects on the ERG and VECP of background lighting levels. From this study, we will learn more about the nature of the electrophysiological measures (ERG and VECP) and of the relative contributions of the rod and cone subsystems. It may lead to an objective assessment of the effectiveness of the visual system under different levels of illumination.

Although much of the color work conducted during the past year used full-field stimulation, some research involved the use of small 1-degree spots of colored light. It was found with these small spots that the angle of regard of the subject was an important factor in determining the size and shape of the response. Most subjects showed a much larger response for flashes appearing between 5 and 10 degrees below the point at which they were looking. For individual subjects, the range in which the largest response was evoked was limited to a few degrees. Z-funding for 1973 will allow us to examine the interactions of color, size, and shape on VECP obtained from different angles of regard. This research may help establish objective guidelines with respect to placement, size, and color of warning indicators on control panels. The data may also enable us to correlate certain components of the VECP with the speed and accuracy of target identification. The findings may have an important bearing on the selection, training, and monitoring of personnel involved in various kinds of detection tasks.

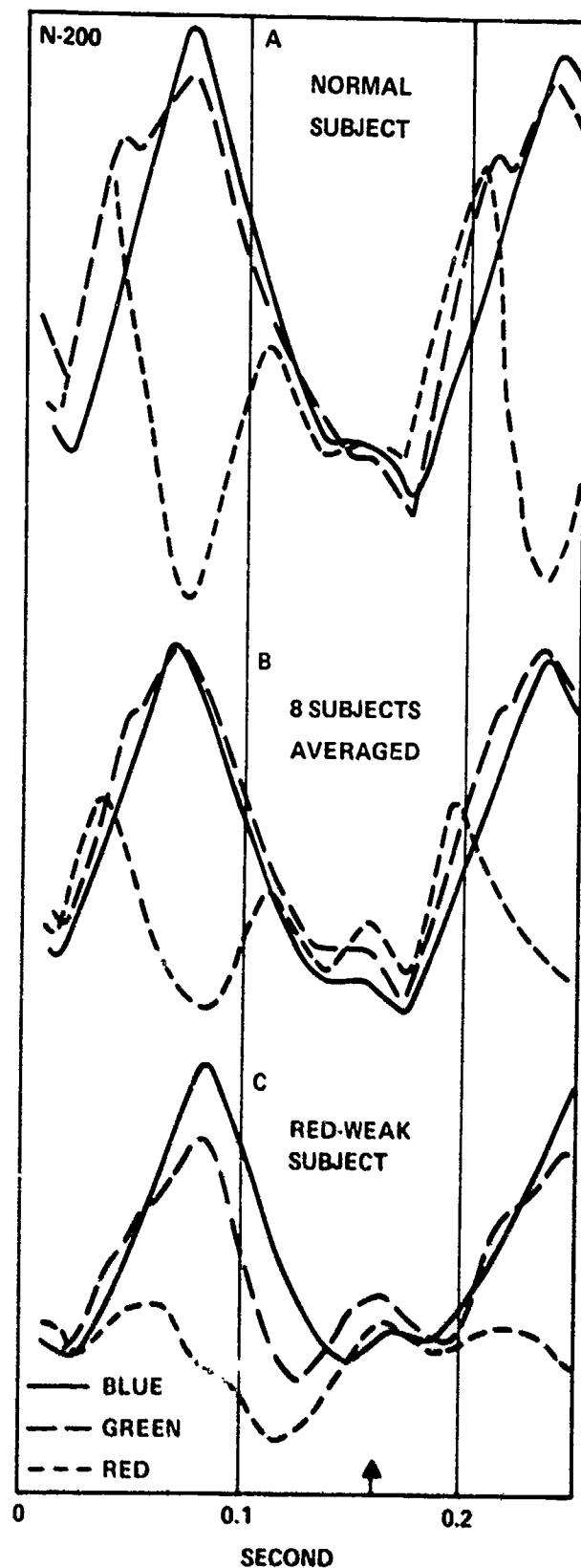
## PUBLICATIONS

An invited paper has been submitted to the American Academy of Optometry:

Martin, J. I., "Color Differences in the Electroretinogram and the Visually Evoked Cortical Potential," *American Journal of Optometry*.

ZR000.01.01  
(NELC Z167)

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225-6677



ERG curves show response to blue, green, and red of a normal subject (set A), eight normal subjects averaged (B), and the color-weak subject (C). Note similarity of sets A and B and noncorrespondence of red response in C. Curve in C is still negative-going at 0.1 sec, whereas other red curves (A and B) are positive-going.

# Power Flow and Thermal Radiation Sensors

Monitoring the thermal radiation profile of electronic components and circuits provides a noncontact method of detecting thermal overloads or thermal runaway, and integration of such procedures into automatic test systems can prevent catastrophic failures or, at least, indicate their location.

The object of this research was to develop inexpensive thin-film radiation thermopiles suitable for thermal monitoring of transistors, vacuum tubes, or passive circuit components. For thermocouple applications a junction must be formed between two materials with opposite-polarity Seebeck coefficients  $\alpha$ , large electrical conductivities  $\sigma$ , and small thermal conductivities  $k$ , with an overall figure of merit  $Z = \alpha^2 \sigma / k$ . Thin films are desirable in order to minimize the response time constant, provide a large surface-to-volume ratio of the junction, and allow photolithographic and vacuum deposition techniques to be used for the construction of multijunction thermocouple arrays. On the basis of these considerations we concentrated our work on thin-film thermocouples and thermopile arrays made by vacuum deposition on mylar substrates. Semimetal-to-semiconductor junctions were made by flash evaporation of the semimetal compound  $\text{Bi}_{0.88}\text{Sb}_{0.12}$ , which, in thin-film form, was found to have the high negative Seebeck coefficient  $\alpha = -103 \mu\text{V}/^\circ\text{C}$ , and the semiconducting compound  $\text{Cd}_{0.25}\text{Sb}_{0.75}$ , with the positive Seebeck coefficient  $\alpha = 145 \mu\text{V}/^\circ\text{C}$ . Films 1500 Å in thickness were deposited through stainless steel masks in order to produce thermopiles, such as those shown in the photographs, with up to 41 thermocouples per thermopile. Typical responsivities of such devices

were found to be 12.2 V/W with a thermal response time constant of 0.1 sec. These devices were used in order to determine the three-dimensional thermal profiles of wire-wound resistors and power transistors in TO-5 cans under normal and abnormal operating conditions of heat dissipation at constant ambient temperature. The normal operational temperature, heating and cooling cycles, and thermal overloads were clearly identifiable.

Two specific problem areas require further investigation: (1) the temperature dependence of  $\alpha$  must be compensated by external circuits or a trade-off in sensitivity; (2) thermal convection represents a perturbation of the thermopile response, and a suitable thermopile enclosure needs to be developed.

Additional applications of thin-film thermocouples and thermopiles were investigated and found feasible. A microwave and rf power detector was built by terminating a coaxial transmission line with a pair of thin-film thermocouples coupled capacitively to the line. Over the frequency range 10 MHz to 3 GHz their response was found to be 0.3 V/W, linear with input power. Potential applications include noncontact monitoring of the operational status of local oscillators and other rf and microwave sources.

## PUBLICATION

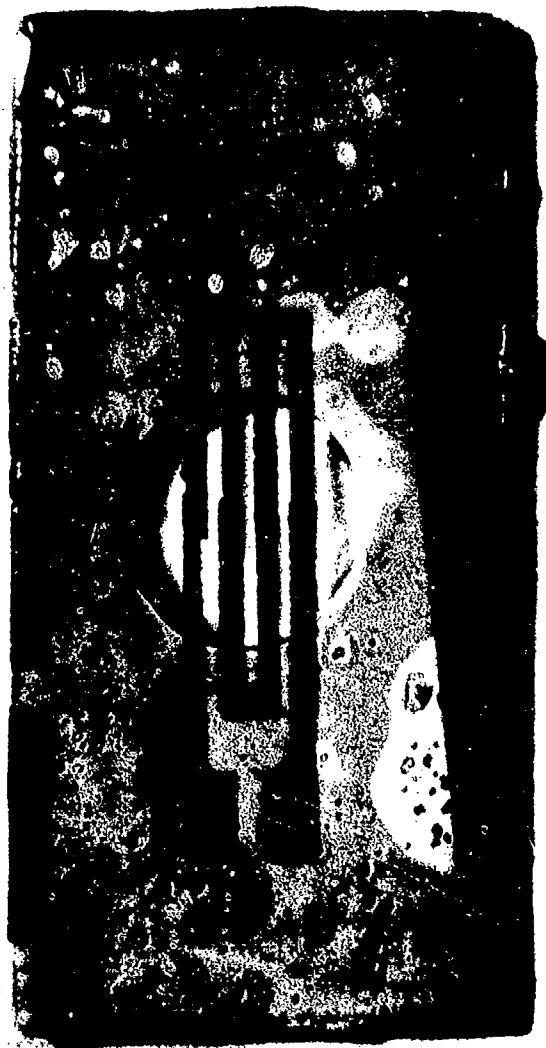
Meiners, L. G., Clawson, A. R., and Wieder, H. H., "Bulk-like Films of Bismuth-Antimony Alloys," paper accepted for Am. Vacuum Soc. Symposium, October 1972, Chicago, Illinois

ZR000.01.01  
(Z172)

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225-6591



*Forty-one element 0.88, 0.12, 0.25, 0.75 thermopile  
on mylar supporting layer.*



*Four-element 0.88, 0.12, 0.25, 0.75 thermopile on  
mylar supporting layer.*



## Advanced Memories Technology

On the basis of study of the relatively well established silicon technologies of bipolar and MOS devices, and of technologies in earlier stages of development—metal-nitride-oxide-semiconductor (MNOS) devices, charge-coupled devices (CCD's), holographic memories, plated wires, amorphous glasses, magnetic films, and others—NELC in FY72 selected MNOS devices and CCD's as the most promising for experimental work in memory technology.

Like MOS devices, MNOS devices can be used in rapid- and random-access solid-state memories. The nitride endows MNOS devices, however, with an additional feature not shared by MOS devices. MNOS memories are nonvolatile—they retain data through power interruptions. This feature is expected to prove valuable in naval applications.

NELC is currently completing the assembly of test

instrumentation to be used in the analysis and characterization of prototype MNOS devices presently on order from a contractor.

NELC also specified and assembled equipment in FY72 to establish a capacity for the fabrication of CCD's at NELC. This capability will allow NELC to contribute to the new technology in design as well as in application.

Under Z2 funding, CCD's will be manufactured at NELC and procured from industry; prototype memory modules will be assembled, tested, and evaluated; and recommendations based on this experience will be made regarding implementation of this nonmainstream technology in Navy systems.

*ZR000.01.01*  
*(NELC Z169)*

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## Bioelectronic Study of Sea Mammals

Bioelectric phenomena in seals and dolphins in response to auditory and visual stimuli are studied under this task—brainwave activity, evoked cortical potentials, heart action, etc. The information may suggest approaches to Navy sonar system design.

So that the animals will be in as natural a situation as possible when measurements are made—swimming freely in a tank or, in the future, in the open ocean—it was decided to develop telemetry devices which would make direct wiring from them unnecessary.

Design of the telemetry system was made difficult first by the problem of achieving adequate range through sea water. The medium is not friendly to rf propagation—especially at high frequency. Low frequency (below 20 kHz), which is best from the standpoint of range, cannot be used because it would be sensed by the subject. Then the package had to be miniaturized for operation within a free-swimming animal.

Following a literature study and visits to telemetry experts at NASA (Ames Laboratory) and UCLA, various transmitter designs were developed and tested. A technical question typical of many that arose: should the transmitting antenna be a coil or should it be a dipole? (Or, in other words, would it be better to use the magnetic field or the electric field for the transmission of the signal?) Experiments showed that use of the dipole antenna would increase the range over which information could be transmitted.

The first model of the telemetry device was built in 1972. NASA, Naval Undersea Research and Development Center (NUC), and UCLA Brain Research Institute designs were used in this system, with NELC modifications. The electroencephalograph (EEG) amplifier is a 1" x 2" equipment which can be mounted on the head of a human subject or implanted in a marine mammal with a transmitter (package dimensions, with transmitter and batteries: 3" x 3" x 1"). It is nearly immune to noise, having high input impedance and differential input. Gain is 100 000 in the present version. In laboratory recording of electroretinograms, visually evoked cortical potentials, and EEG's, this mini-amplifier replaces a floor-standing Offner multichannel amplifier, and permits measurements to be made outside the shielded room which previously had to be used for these experiments.

The amplifier has another potential application in patient-monitoring. The freedom from need for shielding would be an obvious advantage in a hospital room.

Tests on the fidelity of the total system in transmitting brainwave patterns are underway. FY73 will see stationary testing in the NUC 30'-diameter seawater tank. Implantation in a dolphin will follow successful completion of the test program.

ZR000.01.01  
(NELC Z173)

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# LSI-Compatible Permutation Networks for Naval Switching Concepts

The problem of how to design an interconnection network that can connect N input lines to N output lines in an arbitrary manner (a permutation network) and still be able to easily control this network is considered. The systematic determination of the system boundaries has led to a switching concept based on an expandable modular (or cellular) LSI element to solve the intercommunication problems in a computer-controlled communication environment (i.e., how to interconnect memories and processors in a multicomputer system or how to collect and distribute I/O data from many sensors).

The state of the art in switching devices was reviewed. A system analysis demonstrated that LSI can solve the problem by building networks of the complexity necessary to implement computer-controllable permutation networks. Specifically, the investigation addressed and determined the methods to design, partition, and control permutation switching networks suited for LSI production. Thus, depending on system configurations and boundary conditions, four tentative design approaches to a basic LSI building block with low power and high speed requirements were determined.

1. Heuristic search controller with multiplexer (central computer controlled) to find a free path between the desired input and output lines. This is the only solution which satisfies all assumed constraints and is best suited for general use.
  2. Heuristic search controller with "hard wired" distributed computer (multiplexer blocks are replaced by a combination multiplexer/decision element).
  3. Fixed path with system intercepts (data stored in ROM—number of LSI chips reduced).
  4. Fixed path with allowed intrasystem transients.
- Solutions 3 and 4 lend themselves to shipboard installation (they are less costly and more reliable).

From the analysis of these four configurations and the basic assumptions, a set of general I/O characteristics was defined for the design and partition of a bidirectional 8 x 8 basic LSI switching matrix operating at the 10 - 40-

MHz transmittal rate. The circuit has been designed using C-MOS logic gates in MSI form to implement the switching array. Testing and evaluation of this approach have shown a basic limitation of the technology, i.e., maximum frequency transmitted by the C-MOS logic bilateral switches (5 - 10 MHz), effects of staking switches into larger matrices, and need for wave-shaping circuits on the output.

An alternate approach using "transmission" gates as opposed to logic switching gates lends itself to LSI implementation. A single chip, 120 x 160 mils<sup>2</sup>, constitutes the basic cell for a bilateral 8 x 8 matrix operation. Transmission gates with 250 ohms ON resistance P-channel Si-gate MOS eliminate the problems associated with relatively low-speed MOSFET's. (The transmission gates are preprogrammed to be either ON or OFF; i.e., they are not switched at a speed equal to the data rate.) In a multichip expansion mode, a hybrid approach using the above basic cell will require additional high-speed T<sup>2</sup>L logic gates at the output of each data line to alleviate the problem of direct cascading the transmission gates (250 ohms ON resistance). The directionality is accomplished by the provision of two other gates head-tailed with complementary control lines which in turn are addressed by an 8-bit shift register. Power dissipation of this chip is typically 400 mW.

A follow-on study is submitted for approval to pursue and develop the LSI chip based on the results obtained to date.

## PUBLICATIONS

Writer, P. L., *System Design of an N-Permuter Switching Network*, NELC Technical Note 2007, 15 March 1972

Additional publication is planned after the fabrication, implementation, and testing of the basic LSI module to solve a specific Navy-wide problem of multicomputer interconnection system.

ZR021.03  
(NELC Z174)

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## IR Photocathodes for Navy Detection Systems

The electron emission properties of low band-gap semiconductors are examined under the combined influence of a strong electric field and infrared radiation. The ultimate goal is to produce a photocathode that will respond to radiation of wavelengths ranging from the visible out to  $2\text{ }\mu\text{m}$  and beyond. A theoretical model has been developed to describe the photo-field effect in semiconductors, and two avenues of experimental approach have been initiated.

The performance of a semiconductor for photo-field emission has been theoretically characterized by its reduced sensitivity  $S$ , equal to the signal current divided by the dark current times the photon current. The model has been applied to GaSb under expected experimental conditions. It has been shown that  $S$  increases with lifetime, net acceptor concentration, and screening. The screening may be caused by negative surface charges or by an inversion layer. The present calculation assumes nondegenerate carrier distributions, in which case the screening effect of the inversion layer is very weak. An extension of our calculations to degenerate distributions, with an anticipated strong screening effect, is now in progress.

Experimentally, an apparatus has been designed to examine the influence of infrared radiation on field emission from GaSb into vacuum. Samples of p-type

GaSb with a net acceptor concentration of  $1.2 \times 10^{17}$  per  $\text{cm}^3$  at room temperature have been etched into points with 1-to-5- $\mu\text{m}$  radii. These points will produce the high external fields required for a significant photo-field effect. Measurements of the I-V characteristics of these samples are now being carried out.

A parallel experimental approach has also been started for studying the electron emission from InSb and InAs into a dielectric. MIS (metal-insulator-semiconductor) diodes have been fabricated from bulk n-type InSb using an anodically formed layer of  $\text{In}_2\text{O}_3$  for the insulator. The internal photoemission of electrons through the insulator from the semiconductor to the metal has been measured and is found to exhibit a yield of  $\sim .6\%$  for photons of energy  $\sim 3\text{ eV}$ . In an attempt to increase the signal-to-noise ratio of these devices while still retaining the capability of a response to beyond  $2\text{ }\mu\text{m}$ , we are now investigating the use of p-type InAs in this application. It has been found that anodization may also be used on this material to produce a highly insulating and electrically strong dielectric. Measurements of the internal photo-emissive yields of these devices are now in progress.

ZR021.03  
(NELC Z175)

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225-6591

## Surface Barrier Physics and Charge-Coupled Devices

The electrically and optically induced changes in the surface energy band structure of III-V compound semiconductors are of importance for the construction of metal-oxide-semiconductor structures (MOS) for infrared signal-processing applications based on charge coupling and charge transfer technology.

During the past 3 months the main emphasis was placed on the development of compatible oxides for fabricating single MOS structures on InSb and InAs

and a preliminary investigation of the surface barrier physics of these compounds. Surface depletion was found feasible using anodically formed oxides on n-type materials at 77 K. Photon injection measurements and capacitance vs potential measurements presently underway on these MOS structures suggest that infrared bucket brigade shift registers might be feasible.

ZR011.02  
(NELC Z176)

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225-6591

## Narrowband Detector

The objective of this program, begun late in FY72, is to develop a narrowband optical detector for reception of laser radiation against a broadband background with high-speed optics (wide field of view (FOV)). Since interference and other narrowband filters generally have narrow FOV, a new approach is desired to achieve bandwidths  $< 200\text{\AA}$  (preferably  $< 20\text{\AA}$ ) in the 4800–5200- $\text{\AA}$  range.

Two alternate approaches are being investigated: semiconductor narrowband self-filtering photodiodes (NBSFD) and rare-earth activated quantum counters (REQC).

A NBSFD consists of a heterojunction structure with a layer of n-type semiconductor material, having its absorption edge at  $\lambda_1$  forming a p-n junction in a substrate of p-type material with absorption edge at  $\lambda_2 > \lambda_1$ . Thus, only radiation in the band  $\Delta\lambda$  between  $\lambda_2$  and  $\lambda_1$  passes through the layer and excites carriers in the junction; radiation at wavelengths greater than  $\lambda_2$  passes through the detector without exciting carriers while that shorter than  $\lambda_1$  is blocked by the n-type layer.

Present devices have achieved 200–300- $\text{\AA}$  bandwidths in the 7000- $\text{\AA}$ -to-1.1- $\mu\text{m}$  range. Materials are not yet developed for shorter wavelengths.

A REQC consists of a crystal or powder activated with ions of a rare-earth element having a number of

electronic energy levels between which radiative transitions are possible. The detection process involves absorption of a signal photon, which excites an ion to a metastable state, followed by absorption of a photon from a pump source, such as an LED, and then emission of an output photon at a short wavelength, which is readily detected with a conventional detector. The signal, pump, and output wavelengths can be well separated so that simple filtering isolates each from the others. The bandwidth is determined by the linewidth of the signal absorption transition – typically of the order of 1  $\text{\AA}$ . A candidate material for REQC detection at 5145  $\text{\AA}$  is  $\text{LaF}_3:\text{Er}^{+3}$  with bandwidth  $< 3\text{\AA}$ .

The problem of matching the REQC to the laser wavelength may be eliminated by the use of tunable laser sources. The only working REQCs have so far exhibited low quantum efficiency, but they may still offer advantages over other detectors because of their very narrow bandwidths and wide field of view.

ZR021.03  
(NELC Z178)

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225-6591

# Summaries of Independent Exploratory Development Projects

## Surface-Wave Acoustic Devices

This problem is concerned with the application of microwave acoustic devices to the signal-processing functions of existing and future Navy communications/navigation/IFF systems.

During FY72 three sets of surface wave correlators for biphased signals were designed and fabricated and are operational. The first device—an 11-bit Barker code, operating at 45 MHz with a 1-MHz data rate—will be used in a Marine Corps locating system, and also as part of a spread-spectrum modem NELC has designed and demonstrated to be feasible in conjunction with another project. The second device—a 127-bit maximal length code, operating at 60 MHz with a 10-MHz data rate—with minor modification could be used in a major radar system. The actual device was used to test the crossed-field amplifiers of this radar via paired-echo techniques. The third device—a 31-bit maximal length code, operating at 300 MHz with a 5-MHz data rate—will be part of another experimental spread-spectrum system. In the process of developing the above devices, NELC microelectronics laboratory has gained valuable experience in processing techniques. NELC can now fabricate any device within the current state of the art. Such problems as impedance-matching techniques and proper packaging to eliminate rf feed-through have been considered and solved. Computer programs based on the Mason equivalent-circuit models have been written and are operational. These programs will analyze the detailed performance of such devices as FM chirp filters, bandpass filters, and biphase modulators.

Several techniques for achieving very-narrow-bandwidth filters have been investigated. One in particular looks promising, and a device incorporating it will be designed and fabricated in FY73.

A contract is expected from NAVELEX to develop a programmable correlator for a major radar system. In the interim the project will be carried on the IR/IED program. NELC has also been engaged to act as technical support for Naval Air Development Center (NADC) in the development of an advanced pulse compression filter.

NELC is supporting other DoD organizations in the area of surface-wave acoustic devices. NELC aided NADC, Warminster, Pennsylvania, to evaluate a proposal for an advanced surface-wave pulse compression filter, and will be designing and fabricating a series of devices for the National Security Agency.

### PUBLICATIONS

Schiff, M., *Application and Design of Surface Wave Acoustic Devices*, Naval Electronics Laboratory Center Technical Note 2001, February 1972

Schiff, M., *Computer Aided Design of Surface Wave Acoustic Devices*, Naval Electronics Laboratory Center Technical Note 2040, May 1972

ZFXX.512.001  
(NELC 2231)

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225-7982

# Command Control Display Module Study

## BACKGROUND

In an investigation in FY71 as to the applicability of microelectronic modules to display development and fabrication, functional partitioning of the digital logic required for display support was conceived. A number of modules were designed and incorporated into a high-speed CRT stroke-type symbol generator which provided seven-bit parallel digital stroke information at a 10-MHz rate. The modules were:

- Arithmetic/Logic Unit (ALU)
- Free Logic Unit (FLU)
- Multiplexer
- Control Unit 1
- Control Unit 2.

Although problems were encountered with the exact partitioning boundaries, electrical throughput time, and mechanical construction of the module bin, the performance of the symbol generator was encouraging.

## PROGRESS IN FY72

A concerted effort was made in FY72 to eliminate shortcomings. The ALU module was greatly improved in throughput time and versatility via two recent technological improvements for medium-scale-integration transistor-transistor-logic integrated circuits—Schottky-clamped logic and tristate logic. The Multiplexer Unit and Control Units 1 and 2 were completely repartition-

ed and redesigned. Only the FLU module remains unmodified and in need of redesign. Seven module types are believed to have achieved "benchmark" status.

A highly flexible display exerciser has been fabricated with the newly designed module set. It contains the following modules:

- ALU (eight)
- FLU (19)
- Binary Asynchronous Reconfigurable Formatter (four)
- Serial/Parallel Loader and Transceiver (one)
- Decision Tree (two)
- Control Memory Control (one)
- Bootstrap (one)
- Function Control (one)

These 37 modules contain 947 dual in-line packages and are equivalent to approximately 10 800 gates. The exerciser is in the checkout stage and is expected to be operational in August 1972.

## PLANS FOR FY73

It is expected that the Serial Memory and Line Driver/Line Receiver modules will be completed and considerable work accomplished on the Analog modules in FY73. Other applications of the module set will also be investigated.

ZFXX.212.001  
(NELC 2238)

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225-6541



# Universal, Modularized Digital Controller for Analog Power Drives Aboard Ship

## BACKGROUND

Frequently, in Navy applications, an analog power drive must be controlled by positioning commands originating in a centralized (or master) digital computer. Studies performed by NELC personnel on several systems—including gun mounts, missile launchers, and tracking antennas—have indicated the feasibility of a universal digital controller for this class of systems. This study is concerned with the development of a modularized universal controller (minicontroller) utilizing closed-loop digital control techniques and state-of-the-art medium- and large-scale-integration component.

The development of the minicontroller was initiated in FY71 and was directed toward defining specific functions performed by the controller and grouping them logically as modules. These studies led to the design and implementation of four basic modules in a breadboard configuration. The minicontroller incorporates four basic modules. Three of these modules are identical for all systems considered for this application; the fourth is peculiar to the particular type of system being controlled.

## FY72

The basic minicontroller configuration resulting from these earlier studies has remained essentially unchanged. A refinement to the basic breadboard minicontroller model has been the development of a "brassboard" prototype amounting to a first cut at a production operational minicontroller. It incorporates complementary MOS (CMOS) devices in place of some of the P-channel (PMOS) devices used in the breadboard, with benefits in reduced power dissipation and increased speed. More CMOS devices will be fitted into the design as they are de-

veloped and additional sources become available. The brassboard model greatly increases the ease with which operational systems may be tested.

Extensive testing is continuing to demonstrate the minicontroller concept. In-house tests include checkout in the NELC hybrid simulation laboratory and on the 3"/50 gun test facility. In February 1972, successful operational tests were conducted using the Mk 112 ASROC launcher located at NUSC, Newport, R. I.

## FOLLOW-ON AND RELATED TASKS

Other NELC problems will benefit directly and indirectly from the concepts and knowledge gained as a result of this program. For example, the Naval Weapons Laboratory at Dahlgren, Va., has tasked NELC to assist in the modernization and updating of the Mk 68 Gun Fire Control System. This presents another excellent opportunity to demonstrate this controller and may possibly lead to its implementation into this operational system. Additionally, with minor modifications, the minicontroller will be adapted to control a miniature three-axis satellite communication antenna under development at NELC.

Future plans include the completion of the design and specifications for the production model of the minicontroller using all CMOS devices. In addition, a complete system evaluation in an operational shipboard environment is planned.

## PUBLICATIONS

Wells, E. J., Jr., and Doherty, D. W., "A Universal Modularized Digital Controller," 1972 IEEE Region Six (U.S. Western Region) Conference Record, p. 39-41, April 1972

ZFXX 512.001  
(NELC 2239)

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## Optical Multiplexing

The purpose of this joint effort between NELC and NUC is to develop a fiber optics data link incorporated within a small, lightweight tow cable to perform the telemetry function for a towed sonar array.

Multiplexing and electronic components have been synthesized and tested. Visible and infrared light emitting diode optical sources and silicon avalanche and photomultiplier optical detectors have been tested with their electronic drivers and amplifiers. A breadboard 16-channel data encoder—with optical transmission, reception, and decoding—is complete. It transmits data at 2 Mbits/sec through a 100-foot length of high-loss glass, with error rates less than  $5 \times 10^{-7}$ . A three-hydrophone wet array unit is 75% complete and scheduled for sea testing during FY73. In addition to the hydrophones, this unit contains a signal conditioner and a multiplex scanner encoder. Several designs for high-pressure optical feedthroughs have been made, and two survived testing to 3500 psi. Prototype tow cables in-

corporating high-loss optical transmission lines have been procured from industry.

For ultimate systems use, low-loss fiber bundles are essential. One 1000-foot length of low-loss fiber bundle has been received from industry, and two more are on order for test and evaluation at NUC and NELC.

### PUBLICATIONS

Redfern, J. T., and Taylor, H. F., *Fiber Optic Data Link in a Towed Array*, Naval Undersea Research and Development Center Technical Note 595, Sept. 1971  
(CONFIDENTIAL)

ZFXX.212.001  
(NELC Z242)

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225-6641

# Shipboard Error Monitor

## BACKGROUND

The concept for the Shipboard Error Monitor grew out of laboratory instrumentation for hf link and antenna tests. The Navy HF Fleet Broadcast was used for testing data link components, and instrumentation was devised for indirectly measuring bit error rate accurately on any FSK transmission twinned for in-band diversity.

An NELC technical note described the technique (TN 1584, 1969), and application was made for a patent. The technique was applied to a system for enabling shore stations to monitor the quality of their transmissions.

## WORK DESCRIPTION

The effort of the past year has been aimed at producing a prototype model of a MUX quality monitor for shipboard use, an operator aid for use in conjunction with the UCC-1 FSK modem (multichannel FSK teletype). It is intended to help in selecting the optimum frequency for multichannel teletype data reception at hf. Two frequencies can be monitored on it simultaneously, and a 10-minute history of channel quality can be read from two rows of indicator lights.

Design work was initiated in July 1971. Circuit and chassis design, thermal analysis, circuit board fabrication, chassis construction, assembly, and wiring

were all completed at NELC. The unique concept of the Shipboard Error Monitor is implemented in standard logic circuitry. A highlight—the pulse discriminator uses a resettable decade counter to perform a normally analog function digitally with elegant simplicity.

The unit is complete, and is presently being tested in the laboratory.

## FOLLOW-ON

A short project to develop an engineering tool using the MUX quality monitor design—a simple one-channel version with provision for an external chart recorder to be used for studying shipboard rf interference—was derived from this program. The work was done for the Antennas and EMC Branch of the Radio Technology Division.

It is intended that a production bid package be developed for an equipment for use ashore and aboard ship for determining the quality of reception on a ship-shore termination.

*ZFXX.212.001*  
(NELC Z245)

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225-7146

# Improved Techniques for Advanced Shipboard Display Systems

A device competitive with the CRT in display quality and flexibility but without the space requirements and other disadvantages of the CRT has long been sought. In recent years several flat-panel technologies have emerged from the developmental state and devices have become available off the shelf for commercial and industrial use. It is the purpose of this problem to determine the suitability of four of the most promising of the new technologies for use in predicted naval displays.

## FY72 GROUNDWORK

NELC undertook the construction of a display demonstrator in FY72 to facilitate the accomplishment of this task, and procured:

- A plasma display capable of displaying a raster of 512 x 512 dots over an area 8½ x 8½ inches
- A plasma display capable of displaying eight rows of 32 alphanumeric characters
- Seven-segment light-emitting diodes capable of serving as red, green, and amber indicators
- Light-emitting diodes which can present alphanumeric information on 5 x 7 arrays
- Scattering and bilevel reflective and transmissive seven-segment liquid crystals.

The samples will be driven from a display exerciser being completed under Z238. A compatible interface methodology has been established, and nine module types have been developed to enable the exerciser to accommodate

flat-panel technology. The display samples have been mounted, and the electrical interface has largely been designed, fabricated, and installed. Pending availability of the exerciser, the samples are activated via test card.

Also under this problem, NELC investigated potential improvement in performance of CRT phosphors for selected applications. In the first phase of this effort, the feasibility of persistence selection of dual-persistence phosphors by selective filtering was demonstrated, and the purchase of a display tube incorporating this principle was recommended. In the second phase, the properties of rare earth candidates for replacement of existing long-persistence phosphors were investigated. This work was complemented by work done by NELC Electronic Materials Sciences Division under NELC F207, Evaluation Program of Phosphors and Fluorescent Materials for Information Display Systems, for NAVELEX.

## PAYOFF IN FY73

For FY73 the development of additional modules is planned to support the exercise and demonstration of seven-segment, 5 x 7, 7 x 9, and x/y matrix displays of all types. With the completion of the exerciser, it will then be possible to obtain complete control of the modulation characteristics of the displays and to assemble the characterization data needed for a decision as to suitability for Fleet application.

ZFXX.212.001  
(NELC Z247)

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225-6541

## Real-Time Data Processor

The Navy will be stronger from the logistic standpoint when it is able to implement digital systems via a universal architecture and selected GP building blocks. It will be able to find means, from a manageable store of hardware, to deal with the entire spectrum of problems now handled by a profusion of general-purpose and special-purpose processors—fire control, filtering, analysis, tracking, multiplexing, communications.

Processing elements will utilize the advances in integrated microelectronics.

Work and storage capacity will be modularly expandable.

Tailoring to special requirements will be accomplished by means of "firmware" (microprogramming).

New functions will be realizable "instantly."

NELC determined under Z248 in FY72 that such a system is indeed realizable, as demonstrated by a number of minicomputer manufacturers.

The Autonetics D-200 microprogrammable avionics computer uses 15 MOS device types. The Litton C-4 uses read-only memories and an arithmetic unit. The PDP-16 uses a set of register transfer modules—complex interconnections of microelectronic devices—and is tailored to specific applications.

With the feasibility of the concept established, NELC is now at work on the problem of selecting a suitable architecture and GP building blocks. Major requirements are real-time processing and the ability to meet changing requirements with a minimum of software and hardware changes.

The basic strategy is to implement the processor with commonly used functional blocks which can be configured to the application and to implement unorthodox functional requirements and module control via read-only memories (ROM's). Specific tasks are to identify the functional blocks and to determine how to effectively use hardware, software, and firmware. Of special interest are trade-offs between hardware and software.

Computer simulation was selected as the optimum method of evaluating processor design. Simulation provides throughput speeds and helps determine what should be software and what should be hardware.

Most of the effort focuses on the logic—the AND/OR gates. Since a single module might contain several thousand logic gates, it is necessary to simulate at a higher level, where the input to a module would be a 16-bit parallel word.

The CDL III simulation language developed by Y. Chu at the University of Maryland appeared to be suitable. It was exercised, and is believed capable of meeting the objectives of the program.

CDL III has certain difficulties, pertaining chiefly to dimensioning. NELC increased the capacity of the program to accommodate larger arrays. Another difficulty was in the presentation of the output. NELC is at work to simplify the output and improve its readability.

CDL III will ultimately permit the simulation of modular digital processors and permit the development of the microprograms or software well before the hardware is completed.

SIMSCRIPT II also received consideration, but was not used because of funding limitations.

This program is currently being continued as part of the Small Ships Electronics Program (Z253) to actually simulate a processor designed with arithmetic units implemented in LSI microelectronics—the Intel 8008. The 8008 is planned as a central processing unit on a single substrate. It will be usable as a microprogrammed function or controlled directly from software. The simulation of this simple computer on a computer will then be implemented in hardware. The result will give the Navy a significant capability in new hardware/software processor design. It will provide the ability to select and evaluate processor designs without actually implementing the hardware.

ZFXX.312.001  
(NELC Z248)

Contact:  
T. P. Lindgren  
NELC Code 4300  
225-6859

# Processing Techniques for High-Density, High-Speed Semiconductor Memories

Practical techniques have been developed to increase the component density within a unit area/volume of a silicon chip. A 40% savings in chip real estate has been achieved in fabricating bipolar LSI circuits, such as random-access and read-only memories. The present investigations have emphasized the process developments that inexorably determine the practical capabilities and limitations of integrated circuits.

The process is based on a new approach<sup>1</sup> to circuit isolation called "oxide isolation" in which active p-type diffusions that isolate conventional bipolar devices are replaced by passive silicon dioxide regions. The implementation of the oxide isolation technique is based on the principle that silicon can be "selectively" oxidized when a suitable masking pattern against oxidation is applied to the silicon surface. Silicon nitride is selected as the masking medium for two reasons:

1. It remains practically inert during the oxidation phase; i.e., the transformation of silicon nitride into silicon oxynitride is very slow.
2. The diffusion constant of oxygen through silicon nitride is extremely small.

The oxide isolation technique has required the development of silicon nitride deposition at 850°C on an oxidized silicon substrate. As silicon is consumed by the oxidation process, the local formation of silicon dioxide within the confines of an "isolation pattern" imprinted in the silicon nitride film provides isolated islands of n-type material. When the oxide-isolated islands are formed, standard masking and diffusions are used to build double-diffused transistors within a

2- $\mu$ m thick n-type epitaxial layer. Measurements on bipolar transistors fabricated in oxide-isolated wells have shown  $f_t$  in the order of 1.5 - 3 GHz.

A 1024-bit read-only memory (ROM) comprising Schottky barrier diodes for Schottky-clamped circuitry has been chosen as the test vehicle to evaluate the oxide isolation technique. An identical ROM using conventional "isolation diodes" has been fabricated for comparison purposes. The projected LSI oxide-isolated circuit has shown the same access time but greatly reduced cell size. This novel technique is matching the density of MOS devices while retaining the speed advantages of "discrete" bipolar units in integrated form. Furthermore, considerable improvements are accomplished with the dielectrically isolated elements in a radiation environment because the radiation-generated photocurrents (leakage) are reduced.

The development of this technique and improvements derived from the systematic use of the oxidation kinetics have provided a "work horse" technology which is easily applied to LSI. NELC has recommended the oxide isolation technique to the Naval Air Systems Command as a method for meeting specific subsystem requirements in view of the results achieved in this study.

ZFXX.112.001  
(NELC Z249)

Contact:  
I. Lagnado  
NELC Code 4800  
225-6877

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<sup>1</sup>L. H. Clevenger, U.S. patent no. 3534234, 13 October 1970

# Optical Signal Cross Correlator for Active Sonar System

The purpose of this project is to develop an optical cross correlator for use in conjunction with an active sonar system. This is a joint effort utilizing the optical data-processing capabilities of NELC and the sonar technology experience of NUC. In the past year we have taken an idea for an optical processor (which had been conceived under an IR/IED project in FY71) and have experimentally demonstrated the feasibility of the device, studied the types of codes best transmitted, received, and correlated by it, theoretically calculated its capabilities and limitations, designed a prototype system, and ordered the component parts. We are now in process of assembling the system. Next fiscal year will be devoted to testing the prototype system with recorded sonar returns.

The basic principle of the device is as follows: A light source illuminates a photographic reference mask, and a lens images this mask onto the face of an integrating vidicon television camera, via an oscillating mirror. The lens system and the rotating mirror combine to repetitively sweep the image of the mask linearly across the vidicon face. If the mask is composed of several hundred horizontal lines each having a spatial variation in intensity transmittance which is directly proportional to a signal of interest, and if the light source is intensity-modulated with an incoming "live" electrical signal, then the video output of the camera will be the cross-correlation function between the "live" signal and each member of the reference signal library. Thus, several hundred correlation operations are performed simultaneously.

In the device being assembled, the incoming "live" electrical signal will be the echo received by the sonar transducer array, and the reference mask will contain doppler-shifted versions of the transmitted signal. Also, several light sources will be used simultaneously in the same system to allow the parallel processing of several different beams of sonar returns. By proper specification of the mirror velocity and the mask layout, we can produce a system in which the position of the correlation peak occurring in the output plane (on the television monitor) yields the range, direction, and doppler-shift of any target.

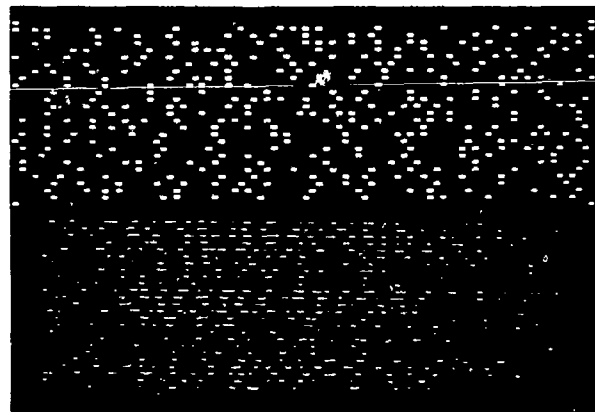
A description of this novel type of correlator is currently being prepared for submission to one of the professional optics journals.

An NELC technical note will be prepared shortly describing the system and its Navy applications.

A patent disclosure has been filed on this concept (Navy case number 53, 286), since it is felt by the authors that the basic simplicity and versatility of the device make it highly suitable for solving many Navy detection and classification problems (including sonar, radar, electromagnetic warfare, and bio-medicine).

ZFXX.112.001  
(NELC Z250)

Contact:  
K. Bromley  
NELC Code 2500  
225-6641



*Twenty-five cross-correlation functions between an incoming signal and a reference library as seen on a TV monitor.*

*The top half of the photograph is a 25-channel mask -- a representation of the reference library. Each line of it is a unique 90-bit random binary code.*

*The bottom half is the correlator output, showing a correlation peak in the center of the fifth channel down. The peak, in this test hookup, indicates that the signal fed into the correlator is the fifth line of the mask.*

*In a more advanced operational system, the correlation peak would indicate the location and the direction and speed of travel of a target. Range would be indicated by horizontal position on the line, direction by coarse vertical position, and doppler information by fine vertical position.*

# A Better Power Supply Miniaturization Technique

The problem of power supply miniaturization techniques addresses the area of improving efficiency, maintaining a high degree of isolation of the source to the load, and maintaining and improving power supply reliability.

A sample circuit design was made indicating that transformer-coupled base drive to the switching regulator power transistor should provide the most economical and adaptable control technique in contrast to control transistor direct-coupled base drive. The problem investigated was the relative switching speed of the transformer-driven and direct-coupled transistor-driven switches.

A test circuit was designed and built to experimentally determine the relative values of transformer and direct-drive power switch characteristics. The power switch chosen was a TRW SVT 350-5. The base drive current was set at 30 milliamperes and the collector current (load) adjusted to 300 milliamperes for a forced beta of 10.

The switch time (turn on) was found to be less than 100 nanoseconds for direct-coupled base drive and approximately 200 nanoseconds for the transformer-coupled base drive. The slower operation with the transformer base drive was further investigated and found to be primarily related to the transformer design characteristics rather than other circuit elements.

Various transformer designs were made and tested to determine the critical transformer design parameters related to the switching regulator application. The physical size of the transformer, the relation of physical placement of primary to secondary, and the magnetic core material high-frequency characteristics were found to be the most significant factors. The experimental results indicated that a very thin lamination molybdenum perm-alloy toroid core with windings uniformly distributed around the circumference produced the best results; i.e., required the least energy to drive the SVT 350-5 and obtained the shortest switch time of the transformers investigated. The ferrite toroid cores in experimental transformers were slower and less efficient.

A complete miniature switching regulator power sup-

ply using transformer isolation and transformer pulse width control drive was built. The switching cycle repetition rate of 30 kilohertz was chosen to obtain adequate overall performance while keeping the magnetic components (transformers and chokes) optimally miniature (e.g., the 5-watt power transformer occupies 1 cubic centimeter and weighs 1 gram; the entire power supply weighs 2 ounces). The fixed frequency control concept is employed to minimize entrainment difficulties, a known problem area in pulse control circuits. The complete power supply circuit was reviewed for application to a high level of integration. It was felt that the total integration could not be accomplished but a high level of integration is possible. There are two LSI candidates within the power supply. The control circuit—consisting of a fixed frequency generator, a comparator, and a reference circuit—may be integrated in one LSI; while the power switch, commutating diode, and source rectifier bridge for universal input applications may be another LSI candidate. A tentative conclusion is that circuit simplification is needed if total integration is to be achieved.

New techniques of employing magnetics and dielectrics are needed to achieve total integration of high-efficiency, low-voltage power supplies producing useful regulated dc power ranging between 5 and 200 watts. NELC's plans for FY73 are to investigate and experimentally test the integrated materials approach—the deposition of magnetic and dielectric materials on a single substrate which can contain the LSI circuitry necessary for a complete power supply.

It is believed that total circuit integration is possible if silicon processing can be made compatible with magnetic materials processing and dielectric materials processing.

Assuming NAVELEX funding, NELC will develop an entire low-voltage power supply family based on the design principles developed under Z funding.

ZF61.312  
(NELC Z251)

Contact:  
L. J. Johnson  
NELC Code 4800  
225-6878



# Liquid Crystal Development

The Liquid Crystal Development Program (Z252) was begun in late December 1971 to investigate the electro-optical properties of liquid crystals (LC's) and explore the application of LC devices for use by the Navy. Specifically, the principles of mode operation (e.g., dynamic scattering, electric-field-induced cholesteric to nematic phase change, and nematic guest-host), the inherent capabilities and limitations of LC's, and the specification of LC system parameters were investigated. Subsequently, motivated by the Navy's need for a two-level voltage-controlled color filter for the dual-persistence phosphor display in NELC Problem Z247, two breadboard systems were constructed and evaluated.

During the first 3 months, an extensive scientific and engineering literature search was implemented on liquid crystals, and experimental equipment and chemicals were ordered.

After laboratory facilities had been established, experiments and cell fabrication techniques designed, and test parameters defined, the final 2 months of FY72 were spent testing voltage-tunable LC cells and determining color tunability, construction parameters, and applicability to a display. The two breadboard systems utilized nematic-dichroic dye guest-host cells and cholesteric mixture cells, respectively. The test results, which are presently being compiled for presentation in a technical report, indicate that for the materials tested, a color shift of only 150 Å was achieved in the guest-host material and at the expense of severe light loss of over 95% due chiefly to the

polarizer-analyzer combination. With the cholesteric material, the filter was easily tunable from the UV into the red with voltages on the order of 100 volts. Since uniformity was very difficult to achieve over anything but a small area and color changes with viewing angle limited the observer to within a cone of about 10° (half angle), an optical coupling system for minimizing the effects of these factors is being designed. In addition to the two-level filter problem discussed above, photoactivated dynamic scattering LC cells were also considered for potential use as a reusable optical recording medium. More specifically, cadmium sulfide deposited on tin oxide-covered glass was investigated for its optical addressability in optical information processing. Fabrication difficulties have slowed this phase of the work, however, but reportable results are expected in the near future.

At present, a paper on a new filter utilizing a photoactivated twisted nematic liquid crystal is being prepared for submission to a scientific journal. The incorporation of this photoactivated intensity filter into two optical systems is under consideration: an image enhancement system (Fluoro-Dodge type) and a spatial attenuator communication and periscope application. A proposal to construct a feasibility model of these two devices has been submitted for in-house Z2 funding.

ZF61.212  
(NELC Z252)

Contact:  
L. B. Stotts  
NELC Code 2500  
225-6641

# Small-Ship Electronic Systems

In order to place an effective command control capability aboard a small ship, crew size must be reduced from today's levels. Electronic systems must somehow make the small ships easier to operate and maintain. Bold new concepts must be put into effect if these objectives are to be realized.

Identifying the essential techniques and technologies and producing a plan to develop them were objectives of the Small-Ship Electronic Systems program, which began in March 1972. New small-ship types such as hydrofoils and surface-effect ships were identified and their probable missions determined. A mission analysis was performed to assess the amount of crew reduction possible through automation. It was apparent that a radically reduced crew could operate the small ships effectively but that the ship's electronic systems had to be reoriented. Mission analysis also pointed out ways to modify some of the weapon systems planned for small ships to extend performance.

A program to develop small-ship electronic systems should be focused in four areas.

1. Operational use of the platforms should be addressed in order to put realistic bounds on crew size, mission duration, payload, threat, etc.
2. New systems concepts need investigation for small-ship use, particularly systems making use of electro-optic technology for communication, search and detection, and tracking and control. Combining these two efforts to evolve methods of coordinating several small ships and other platforms is necessary. Some coordination concepts have been produced.
3. Current technology must be evaluated to solve small-ship electronic system problems such as digital filtering, tracking, and navigation computations.
4. Substantial effort is needed in the area of systems integration to answer a number of questions: How should small-ship electronic systems be packaged to meet environmental problems? What interconnect techniques are satisfactory? How should the system be

tested and maintained? Can computer aids be used to reduce and standardize design costs and procedures?

The development tasks started in FY72 are listed below.

A microprogrammed calculator is being fabricated to compute the closest point of approach (CPA) between two ships. This is a commonly used navigation function. The CPA calculator uses off-the-shelf LSI components and can accept manual or digital data inputs.

Available LSI digital filter devices are being procured for evaluation. These devices have application in target track smoothing and control systems.

A coherent i-f signal combiner is being breadboarded for hf radios. Use of such a combiner can alleviate the severe hf antenna placement problem on small platforms.

Available computer functional simulation tools have been surveyed, and work in modifying them to fit some of the available state-of-the-art functional LSI devices is in process. The microcomputer-on-a-chip devices are being programmed for the CPA application.

Use of data bus techniques and distributed microprocessors to provide integration of small-ship electronic systems is being investigated. This approach provides flexibility to change portions of the electronics suit and also provide real-time quick-reaction capability for the complete mission equipment.

A study of low-loss energy transfer and conversion materials and techniques is being performed with the goal of high-efficiency, low-mass power supply systems for small ships.

## PUBLICATIONS

A NELC technical note covering the tasks in the Small-Ship Electronic Systems program will be published in the fall of 1972.

ZF61.212  
(NELC Z253)

Contact:  
W. J. Dejka  
NELC Code 4300  
225-6861

# Publications and Presentations

## Papers Submitted for Publication

### INDEPENDENT RESEARCH

- Gabriel, C. J., "Faraday Rotation of a System of Thin Layers Containing a Thick Layer," *Applied Optics* 10, 2332, October 1971
- Gabriel, C. J., and Nedoluha, A. K., "Transmittance and Reflectance of Systems of Thin and Thick Layers," *Optica Acta*, v. 18, no. 6, p. 415-423, 1971
- Zaeschmar, G., and Nedoluha, A. K., "Theory of the Optical Properties of Gold Blacks," *J. Optical Soc. America*, v. 62, no. 3, p. 348-352, March 1972
- Schade, W. J., Jr., "Accurate Measurements for Cyanic Laser Wavelengths Using Resonator Interferometry," *Optics Communications*, v. 4, no. 6, p. 399-403, Feb/Mar 1972
- Rast, H. E., Miller, S. A., and Caspers, H., "Infrared Active Lattice Vibrations of BaBrF," to be published in *Journal of Chemical Physics*
- Martin, J. I., "Color Differences in the Electroretinogram and the Visually Evoked Cortical Potential," submitted to the American Academy of Optometry, *American Journal of Optometry*
- Martin, W. E., and Hall, D. B., "Diffused Waveguides in II-VI Compounds," *Applied Physics Letters* (to be published)
- Taylor, H. F., Smiley, V. N., Martin, W. E., and Pawka, S. S., "Fluorescence of Graded-Band-Gap  $\text{CdS}_x\text{Se}_{1-x}$  Crystals Produced by Diffusion," *Physical Review B*, 1467 (1972)
- Taylor, H. F., Martin, W. E., Hall, D. B., and Smiley, V. N., "Fabrication of Single-Crystal Semiconductor Optical Waveguides by Solid State Diffusion," *Applied Physics Letters*, 1 August 1972

## In-house Publications

### INDEPENDENT RESEARCH

- Hill, J. R., *A Method for Rapid Computations of VLF, Steep-Incidence Reflections from the Ionospheric D-Region*, Naval Electronics Laboratory Center Technical Report 1784, 19 August 1971
- Shellman, C. H., *A Profile Inversion Method Applied to Finding D-Region Electron Densities from VLF Reflection Data*, Naval Electronics Laboratory Center Technical Note 2030, 3 May 1972
- McCall, D. C., *A Walsh Transform Source Encoding Technique for Bandwidth Reduction*, Naval Electronics Laboratory Center Technical Note (in preparation)
- McCall, D. C., *Computer Programs for Walsh Analysis*, Naval Electronics Laboratory Center Technical Note 1986, 6 January 1972
- Marez, J., *Liquid Crystal Display Techniques*, Naval Electronics Laboratory Center Technical Report 1829, 8 June 1972
- Writer, P. L., *System Design of an N-Permuter Switching Network*, Naval Electronics Laboratory Center Technical Note 2007, 15 March 1972

### INDEPENDENT EXPLORATORY DEVELOPMENT

- Schiff, M., *Application and Design of Surface Wave Acoustic Devices*, Naval Electronics Laboratory Center Technical Note 2001, February 1972
- Schiff, M., *Computer Aided Design of Surface Wave Acoustic Devices*, Naval Electronics Laboratory Center Technical Note 2040, May 1972

Conference on Fiber Optics Communications 1-3 March 1972, abstracts of papers presented, contractors and DoD agencies, published by NELC Code 2500

Redfern, J. T., and Taylor, H. F., *Fiber Optic Data Link in a Towed Array*, Naval Undersea Research and Development Center Technical Note 595, September 1971 (CONFIDENTIAL)

## Invited Presentations at Professional Meetings

### INDEPENDENT RESEARCH

Shellman, C. H.

"The Inversion of VLF/LF Sounder Data to Obtain D-Region Electron-Density Distributions," to be published in "Proceedings of a Workshop on the Mathematics of Profile Inversion (Ames Research Center, July 1971)," edited by L. Colin, NASA TMX-6 2150, 1972

Taylor, H. F., Smiley, V. N., Martin, W. E., and Pawka, S. S.

"Fluorescence of Graded-Band-Gap  $\text{CdS}_x\text{Se}_{1-x}$  Crystals Produced by Diffusion," American Physical Society Winter Meeting, Cambridge, Mass., December 1971

Taylor, H. F., Martin, W. E., Smiley, V. N., and Hall, D. B.

"Fabrication of Integrated Optical Circuits by Solid State Diffusion," Optical Society of America Topical Meeting on Integrated Optics, Las Vegas, February 1972

Hall, D. B., and Martin, W. E.

"Diffused Waveguides in II-VI Compounds," VII International Quantum Electronics Conference, Montreal, May 8, 1972

Hall, D. B., and Martin, W. E.

"Diffused Optical Waveguides and Platelet Lasers," Navy-Wide Laser Conference, NELC, November 10, 1971

Lagnado, I., and Schiff, M.

"Programmable Coding Techniques for Semiconductor/Acoustic Surface Devices," 1972 IEEE Region Six Conference, San Diego, California

Martin, J. I.

"The Role of a Research Psychologist--Investigations Into Electro-Physiological Psychology," Psychology Department, Central Missouri State, Warrensburg, Missouri, 25 October 1971

"Differences in the Cortically Evoked Potential Related to Color," American Academy of Optometry, Toronto, Canada, 13 December 1971

"Electrical Responses of the Human Visual System," Society of Display Information Engineers, San Diego, California, 8 February 1972

"Color Differences in Electrophysiological Responses," Neurosciences Department, University of California at San Diego, San Diego, California, 5 April, and Psychology Department, San Diego State College, San Diego, California, 25 April 1972

White, C. T.

"Binocular Summation Effects in the Cortical-Evoked Potential," American Academy of Optometry, Toronto, Canada, 13 December 1971

Meiners, L. G., Clawson, A. R., and Wieder, H. H.

"Bulk-like Films of Bismuth-Antimony Alloys," accepted for American Vacuum Soc. Symposium, Chicago, Illinois, October 1972

### INDEPENDENT EXPLORATORY DEVELOPMENT

Wells, E. J., Jr., and Doherty, D. W.

"A Universal Modularized Digital Controller," 1972 IEEE Region Six Conference, San Diego, California

Williams, D. N., and Redfern, J. T.

"Applied Fiber Optics Communications in Navy Systems," DoD Conference on Fiber Optics Communications, San Diego, California, 1 March 1972

Hood, J. M., Jr., and Albares, D. J.

"Fiber Optics Technology and Applications," Fiber Optics Workshop, Navy-Wide Electro-Optics Meeting at NOL,  
White Oak, July 1971

Taylor, H. F.

"Fiber Optics Communication System Considerations," DoD Conference on Fiber Optics Communications, San Diego,  
California, 1 March 1972

# Patent Activity

## Independent Research

### PATENTS ISSUED

**D. E. Altman and M. Geller**

*Selectively Controllable Radiant Energy Device*

A gaseous discharge device is made to emit radiant energy in a desired spectral region by the application of an appropriate magnetic field having a direction perpendicular to the electric field resultant from the flow of current through the gaseous discharge device.

Patent No. 3,611,191 (Navy Case No. 46,617) Serial No. 873,323 Filed 3 Nov 1969 Issued on 5 Oct 1971

**V. N. Smiley**

*Thin Film Laser*

The present invention is directed to providing a thin film laser including a pair of spaced highly reflective surfaces having a thin film of semiconductor interposed therebetween, the resonant frequency of which is dependent on the spacing. Pumping by optical or electron bombardment produces an emitted coherent light in a narrow beam in a direction perpendicular from the film.

Patent No. 3,579,142 (Navy Case No. 47,272) Serial No. 842,938 Filed 18 July 1969 Issued on 18 May 1971

**V. N. Smiley**

*Thin Film Active Interference Filter*

High resolution optical filtering using the combined properties of interference filters and laser amplification. Hence to act as an amplifying filter for visible ultraviolet or infrared wavelengths.

Patent No. 3,579,130 (Navy Case No. 50,200) Serial No. 842,917 Filed 18 July 1969 Issued on 18 May 1971

**H. H. Wieder and D. A. Collins**

*Method of Making Raster Pattern Magnetoresistors*

Patent No. 3,592,708 (Navy Case No. 47,745) Serial No. 748,069 Filed 26 July 1968 Issued 13 July 1971

**N. M. Davis and A. R. Clawson**

*Controlled Nucleation in Zone Recrystallized InSb Films*

Patent No. 3,600,237 (Navy Case No. 49,351) Serial No. 885,923 Filed 17 Dec 1969 Issued 17 August 1971

**A. R. Clawson and H. H. Wieder**

*Sulphur Doped Recrystallized InSb Films*

This process allows controlled crystallization of donor doped InSb films on amorphous substrates, which have the semiconducting properties of bulk InSb.

These InSb films are suitable for use as Hall generators and magnetoresistors because of their sensitivity to magnetic fields and their small thickness. The sulphur doping provides a much smaller variation in the Hall voltage with temperature, thus allowing improved temperature stability over Hall generators made with very pure InSb films.

Patent No. 3,591,429 (Navy Case No. 47,662) Serial No. 747,511 Filed 25 July 1968 Issued on 6 July 1971

**A. R. Clawson, H. H. Wieder, N. M. Davis, and D. A. Collins**

***Lamellar Eutectic InSb Sb Films as Infrared Polarizers***

This infrared polarizer consists of a thin film of closely spaced strips of I.R. transparent semiconducting InSb and I.R. opaque Sb, produced directly by zone crystallization of InSb/Sb eutectic films.

Such polarizers are useful for both digital and analog information processing for CO<sub>2</sub> lasers. They can be used as high frequency phase modulators, rotators and circulators.

Patent No. 3,671,102 (Navy Case No. 50,225) Serial No. 106,800 Filed 15 January 1971 Issued on 20 June 1972

**NOTICE OF ALLOWANCE**

**E. J. Schimitschek and J. A. Trias**

***Method of Preparation of Rare Earth (III) Phosphorus Dichlorides and Phosphorus Dibromides***

A new method of preparation of rare earth (III) phosphorus dichlorides and phosphorus dibromides.

(Navy Case No. 52,876) Serial No. 110,920 Filed 29 January 1971 Notice of Allowance 31 May 1972

**PATENT APPLICATIONS FILED**

**M. Geller, D. E. Altman, and G. J. Barstow**

***High Efficiency Metal Lamps for Dye Laser Excitation***

A high efficiency metal vapor lamp provides desired laser excitation energy without the use of a high temperature furnace as practiced in the prior art and reduces corrosive effects of reactive metals.

(Navy Case No. 53,178) Serial No. 192,857 Filed 27 October 1971

**A. R. Clawson**

***Alloy Zone Crystallization of InSb Thin Films***

This invention is a process for zone crystallizing thin films of semiconducting InSb at temperatures significantly below the melting temperature of the compound InSb. A molten alloy zone of InSb is generated on a vacuum deposited film of stoichiometric InSb by a small diameter heater wire placed close to the film in an inert gas atmosphere. This low melting temperature alloy zone is then scanned across the vacuum deposited film to allow growth of good quality thin film InSb.

(Navy Case No. 53,415) Serial No. 230,862 Filed 1 March 1972

**N. M. Davis**

***Hot-wire Zone Crystallization Apparatus for Thin Films***

The purpose of this apparatus is to crystallize films of a compound or elemental semiconductor on a low thermal conductivity substrate by means of moving a molten zone through the film. The molten zone is produced by heat from a hot wire held in close proximity to the film/substrate. The atmosphere surrounding the molten zone is controlled; that is, can be a vacuum or gaseous atmosphere of selected composition and pressure. The apparatus is designed to be modular in construction to allow ease in experimental modification and application.

(Navy Case No. 53,632) Serial No. (Not available) Filed 29 June 1972

**E. J. Schimitschek and J. A. Trias**

***A Liquid Laser Solution Formed with a Neodymium Salt in Phosphorus Oxychloride***

An improved liquid lasing solution which does not deteriorate with time nor as a result of flash excitation.

(Navy Case No. 48,148) Serial No. 111,128 Filed 29 January 1971

**T. G. Pavlopoulos**

*Improved Dye Laser*

A new type of "quencher" for use with dye laser solutions which greatly enhances their efficiency of operation.

(Navy Case No. 52,545) Serial No. 149,065 Filed 1 June 1971

**M. Geller, D. E. Altman and G. J. Barstow**

*A Light Source for Use in Deep Ocean Water*

A new high intensity light source having a spectral emission very closely matched to the maximum transmissivity of sea water from relatively shallow depths to extreme depths.

(Navy Case No. 52,977) Serial No. 158,330 Filed 30 June 1971



# Independent Exploratory Development

## PATENTS ISSUED

**E. J. Schimitschek**

*Rotating Liquid Cooled Liquid Laser Cell*

A rotating liquid laser cell mounted in a casing providing a coolant-filled chamber surrounding the rotatable cell. The coolant is pumped through the chamber and through a heat exchanger. The arrangement of the components is believed novel. The components themselves are known.

Patent No. 3,654,568 (Navy Case No. 48,147) Serial No. 110,904 Filed 29 January 1971 Issued on 4 April 1972

**E. J. Schimitschek**

*Laser Stimulator Assembly*

A tubular light source closely coupled to an elliptical reflector working in conjunction with two cylindrical retro-reflectors and two plane reflectors for the purpose of reflecting as much energy as possible into a laser cavity, externally connected to the cavity for purposes of greater output laser power.

Patent No. 3,668,546 (Navy Case No. 49,219) Serial No. 105,447 Filed 11 January 1971 Issued 6 June 1972

**G. J. Barstow**

*Multi-Channel Frequency Monitor*

Provides frequency channel and tolerance check for AN/UCC-1(v) Equipment which is readily useable by unskilled, untrained operators.

Patent No. 3,667,051 (Navy Case No. 50,507) Serial No. 117,573 Filed 22 February 1971 Issued 30 May 1972

**J. F. Bryant and W. T. Hyde**

*Method for Making an Optical Filter for a Character Identification System*

The unique method of fabricating the mask of two-dimensional diffractions required in the system of U.S. Patent 3,571,603.

Patent No. 3,656,838 (Navy Case No. 51,944) Serial No. 69,678 Filed 4 September 1970 Issued 18 April 1972

## PATENT APPLICATIONS FILED

**K. Bromley**

*Multi-Channel Optical Correlator System*

A high-speed, multi-channel, optical correlation system employing non-coherent light.

(Navy Case No. 53,286) Serial No. 234,749 Filed 15 March 1972

**R. L. Dickson, George B. Johnson and Kirby W. Hansen, Jr.**

*Performance Monitor Unit for Frequency Multiplexed HF Modems*

Apparatus for monitoring bit error rate of frequency multiplexed FSK transmissions by transmitting frequency-diversity signals to provide in-band, diversity reception which is used to provide comparative performance measurements of BER between twinned tones or between pairs of twinned tones.

The apparatus can be used to provide frequency management on every ship equipped with the UCC-1 modem and would greatly increase operational effectiveness thereof by significantly decreasing the number of missed messages in the Fleet Broadcast.

(Navy Case No. 51,423) Serial No. 106,522 Filed 14 January 1971

## AUTHORIZED INVENTION DISCLOSURE

**Leo J. Johnson**

*A New Concept for Power Supply Design*

A micro-miniaturized power supply using open loop voltage regulation with pulse width control.

Can be used in all electronic circuits requiring a low voltage power source.

(Navy Case No. 54,521) Authorized 10 April 1972

## DISCLOSURES FORWARDED FOR EVALUATION

**J. J. Symanski and R. H. Ebert**

*Integrated Parallel-Serial-Parallel Connector*

A cable connector including logic circuitry to perform parallel to serial to parallel functions reducing need for multiple parallel data lines.

(Navy Case No. 54,948) Forwarded for evaluation 3 May 1972

**D. N. Williams**

*Fiber Optic to Electronic Interface*

A fiber optic-to-electronic interface circuit.

(Navy Case No. 55,085) Forwarded for evaluation 2 June 1972

# Independent Research Projects Terminated

## 30 June 1972

NELC Problem	Title	NARDIS Key	Reason for Termination
Z155	Application of Walsh Functions to $C^3$	DN112050	Into 6.2 funding: ZF61-112 (Z257) Transform Source Encoding Technique for Bandwidth Reduction in Digital Image Transmission
Z168	Development of Liquid Crystal Display Techniques	DN213059	Feasibility demonstrated; ready for 6.2 funding
Z169	Advanced Memories Technology	DN213060	This led to a funded program: Charge Coupled Device Technology Support, NAVELEX 033, XF54.545.021
Z172	Power Flow and Thermal Radiation Sensors	DN213061	Feasibility of radiation thermopiles established; ready for 6.2 funding

# Independent Exploratory Development Projects Terminated 30 June 1972

NELC Problem	Title	ED Task Area	NARDIS Key	Reason for Termination
Z231	Microwave Acoustic Signal Processing Devices	ZF61-512	DN112046	Funding by NAVELEX is expected
Z245	Development of a Shipboard Quality Monitor for HF Multichannel Circuits	ZF61-212	DN112130	Completed
Z246	Fiber Optic Communica- tion	ZF61-212	DN213045	Funding by NAVELEX is expected
Z248	Design of Navy Real-Time Data Processors	ZF61-312	DN213047	Completed
Z249	Investigation of Processing Techniques for High-Density, High-Speed Semiconductor Memories	ZF61-112	DN213048	Completed

## Active Independent Research Projects for FY72

NELC Problem	Title	Principal Investigator	Autovon	NELC Mail Code	Research Requirement	Funding, \$K	NARDIS Key
Z135	Lower Ionospheric Physics (Communications Support)	W. F. Moler	952-7677	2200	ZR021-01	100	DN 848016
Z155	Application of Walsh Functions to C <sup>3</sup>	D. C. McCall	952-6258	3300	ZR014-02	57.5	DN 112050
Z162	Very Fast Integrated Optical Circuits	Dr. D. J. Albares	952-7831	2500	ZR021-03	76	DN 112124
Z163	Specialized New Phosphor Materials for Application to Optical Display and Sensor Technology	Dr. H. H. Caspers	952-6592	2600	ZR011-02	64	DN 112125
Z164	A Tunable Interatmospheric Laser Transmitter for Overt-Covert Communication System	Dr. W. J. Schade	952-6592	2600	ZR011-07	75	DN 112126
Z165	Compatible MOS/LSI and Surface Wave Technologies	Dr. I. Lagnado	952-6877	4800	ZR021-02	47	DN 213056
Z166	Natural Language Processing	D. L. Small	952-7941	5200	ZR014-10	38	DN 213057
Z167	Diagnosis of Color Anomalies by Means of Evoked Cortical Potential	Dr. J. I. Martin	952-6677	3400	ZR042-01	42	DN 213058
Z168	Development of Liquid Crystal Display Techniques	J. Marez	952-7047	3100	ZR021-03	40	DN 213059
Z169	Advanced Memories Technology	R. S. Rios	952-6515	3200	ZR021-03	75	DN 213060
Z172	Power Flow and Thermal Radiation Sensors	H. H. Wieder	952-6591	2600	ZR021-03	52.5	DN 213061
Z173	Bioelectronic Study of Marine Mammals	Dr. C. T. White	952-6677	3400	ZR042-01	50	DN 213062
Z174	LSI Compatible Permutation Networks for (Implementation of) Novel Switching Concepts	Dr. I. Lagnado	952-6877	4800	ZR021-03	25	DN 213138
Z175	Infrared Photocathodes for Navy Detection Systems	Dr. C. R. Zeisse	952-6591	2600	ZR021-03	25	DN 213139
Z176	Surface Barrier Physics and Charge Coupled Devices	H. H. Wieder	952-6591	2600	ZR011-02	10	DN 213140
Z177	Magnetosphere Instability Investigations	V. E. Hildebrand	952-7919	2200	ZR021-01	10	New

## Active Independent Exploratory Development Projects for FY72

NELC Problem	Title	Principal Investigator	Autovon	NELC Mail Code	ED Task Area	Funding, \$K	NARDIS Key
Z231	Microwave Acoustic Signal Processing Devices	Dr. M. L. Schiff	952-6634	2400	ZFXX-512	100	DN 112046
Z238	Command Control Display Module Study	F. C. Martin	952-6541	3100	ZFXX-212	80	DN 112044
Z239	Control System Modules	D. W. Doherty	952-6258	3300	ZFXX-512	80	DN 112070
Z242	Optical Data Multiplexing	Dr. D. J. Albares	952-7831	2500	ZFXX-212	73	DN 112087
Z245	Development of a Shipboard Quality Monitor for HF Multichannel Circuits	R. L. Dickson	952-7146	2100	ZFXX-212	40	DN 112130
Z246	Fiber Optic Communication	Dr. D. J. Albares	952-7831	2500	ZFXX-212	175	DN 213045
Z247	Development of Improved Display Techniques for Advanced Shipboard Display Systems	F. C. Martin	952-6541	3100	ZFXX-212	135	DN 213046
Z248	Design of Navy Real-Time Data Processors	W. J. Dejka	952-6859	4300	ZFXX-312	41	DN 213047
Z249	Investigation of Processing Techniques for High-Density, High-Speed Semiconductor Memories	Dr. I. Lagnado	952-6877	4800	ZFXX-112	40	DN 213048
Z250	An Optical Signal Cross-Correlator for Active Sonar	K. Bromley	952-6641	2500	ZFXX-112	78	DN 213049
Z251	Advanced Integrated Material Power Supply	L. J. Johnson	952-6878	4800	ZF61-312	39	DN 213141
Z252	Liquid Crystal Device Development	Dr. D. J. Albares	952-7831	2500	ZF61-212	50	DN 213142
Z253	Small Ship Electronics Systems	W. J. Dejka	952-6859	4300	ZF61-212	102	New

# Independent Research Program for FY 73

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	Research Requirement	Funding, \$K	NARDIS Key
Z135	Lower Ionospheric Physics (Communications Support)	W. F. Moler	952-7677	2200	ZR021-01	65	DN848016
Z162	Guided Wave Optics	Dr. D. B. Hall	952-6641	2500	ZR021-03	20	DN112124
Z163	Specialized New Phosphor Materials for Application to Optical Display and Sensor Technology	Dr. H. H. Caspers	952-6591	2600	ZR011-02	65	DN112125
Z164	A Tunable Interatmospheric Laser Transmitter for Overt-Covert Communication Systems	Dr. S. A. Miller	952-6591	2600	ZR011-07	75	DN112126
Z165	Compatible MOS/LSI and Surface Wave	Dr. I. Lagnado	952-6877	4800	ZR021-02	65	DN213056
Z166	Natural Language Development	D. L. Small	952-7941	5200	ZR014-10	31.5	DN213057
Z167	Color-Evoked Responses	Dr. J. I. Martin	952-6677	3400	ZR042-01	30	DN213058
Z173	Bioelectronic Study of Marine Mammals	Dr. C. T. White	952-6677	3400	ZR042-01	25	DN213062
Z174	LSI-Compatible Permutation Networks for (Implementation of) Novel Switching Concepts	Dr. I. Lagnado	952-6877	4800	ZR021-03	?	DN213138
Z175	Infrared Photocathodes for Navy Detection Systems	Dr. C. R. Zeisse	952-6591	2600	ZR021-03	25	DN213139
Z176	Surface Barrier Physics and Charge Coupled Device Applications	H. H. Wieder	952-6591	2600	ZR011-02	35	DN213140
Z177	Magnetosphere Instability Investigations	V. E. Hildebrand	952-7919	2200	ZR021-01	50	New
Z178	Narrow Band Optical Detectors	Dr. S. A. Miller	952-6591	2600	ZR021-03	10	New
Z179	Schalkwijk Algorithm	J. C. Lawrence	952-6266	2400	ZR014-08	30	New
Z180	E-O Crystal Storage	Dr. H. F. Taylor	952-6641	2500	ZR011-02	20	New
Z181	Research in Biopotential Technology	Dr. C. T. White	952-6677	3400	ZR042-01	40	New

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	Research Requirement	Funding, \$K	NARDIS Key
Z182	Simultaneous Automatic Recording and Automatic Processing of Echocardiograms and Other Physiological Data	D. G. Mudd	952-6257	3300	ZR041-20	40	New
Z183	Hard Copy Technology Improvements	F. C. Martin	952-6541	3100	ZR021-03	45	New
Z184	Electromagnetic Investigation of Chaff Clouds	J. H. Provencher	952-7098	2300	ZR021-05	30	New
Z185	Feasibility of Photo-Modulating Ship	W. M. Chase, Jr.	952-7701	2100	ZR011-07	6	New
Z186	Kinetics and Effects of Hydrogen at the Si-SiO <sub>2</sub> Interphase	Dr. S. J. Szpak	952-6591	2600	ZR011-02	35	New
Z187	Optical Waveguide Propagation Theory	Dr. R. A. Pappert	952-7688	2200	ZR021-01	35	New



# Independent Exploratory Development Program for FY 73

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	ED Task Area	Funding, \$K	NARDIS Key
Z238	BAMS Command Control Display Module	F. C. Martin	952-6541	3100	ZF61-212	40	DN112044
Z239	BAMS Control System Modules	D. W. Doherty	952-6258	3300	ZF61-512	35	DN112070
Z242	Optical Data Multiplexing (Towed Acoustic Arrays)	Dr. H. F. Taylor	952-6641	2500	ZF61-212	38	DN112087
Z247	Development of Improved Display Techniques for Advanced Shipboard Display	F. C. Martin	952-6541	3100	ZF61-212	62	DN213046
Z250	An Optical Signal Cross Correlator for Active Sonar	K. Bromley	952-6641	2500	ZF61-112	44	DN213049
Z251	Advanced Integrated Material Power Supply	L. J. Johnson	952-6878	4800	ZF61-312	60	DN213141
Z252	Liquid Crystal Device Development	M. A. Monahan	952-6641	2500	ZF61-212	70	DN213142
Z253	Small Ship Electronic Systems	W. J. Dejka	952-6859	4300	ZF61-212	48	New
Z254	Tuned HF Antenna System for Small High-Speed Ships	H. K. Landskov	952-7860	2100	ZF61-512	65	New
Z255	Charged Coupled Device Bulk Storage Memory	J. J. Symanski	952-6515	3200	ZF61-212	40	New
Z256	Hardwired Information Exchange System	Dr. D. O. Christy	952-6515	3200	ZF61-212	40	New
Z257	Transform Source Encoding Technique for Bandwidth Reduction in Digital Image Transmission	D. C. McCall	952-6257	3300	ZF61-112	50	New
Z258	Speech Processing for Radio Communication	C. R. Allen	952-7372	3400	ZF61-212	37	New
Z259	At Sea Tactical Command and Control System Study	G. E. Ereckson	952-6268	0200	ZF61-212	65	New
Z260	Switching Regulator Technology	L. J. Johnson	952-6878	4800	ZF61-512	57	New
Z261	Fiber Optics Emitter/Detector Evaluation	Dr. S. A. Miller	952-6591	2600	ZF61-212	70	New

NFLC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	ED Task Area	Funding, \$K	NARDIS Key
Z262	Evaluation and Development of CMOS Technology	Dr. I. Lagnado	952-6877	4800	ZF61-512	45	New
Z263	LSI Digital Filter Development	C. A. West	952-7023	4800	ZF61-512 ZF61-112	50	New
Z264	Adaptive Array Antenna Development	J. H. Provencher	952-7098	2300	ZF61-112	30	New
Z265	Time and Frequency Domain Reflectometry Techniques	J. W. Troy	952-7232	4500	ZF61-512	52	New
Z266	Solid-State Oscilloscope/Analyzer for Fleet Electronics Support	J. W. Troy	952-7232	4500	ZF61-512	50	New

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13. ABSTRACT  This document is an overview of the NELC IR & IED programs. It summarizes the accomplishments achieved within each project in FY 72. Longer articles are presented on three of the most significant projects - integrated optical circuits, fiber optics communications, and luminescent and electronic materials.		

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